New Trends in Building Automation for Offices of the Future

Jan Haase[1], Dominik Meyer[2]

Abstract: Many office buildings today have the serviceableness and comfort of 40 years old standards. Due to limited budget especially the public authorities are not able to change the edificial status very often. However, there are developments of features or devices in modern building automation that can drastically increase the level of safety, security, comfort, energy saving, and other areas.

This includes trends such as modern elevator concepts moving more than one cabin per shaft and thus generating a much better throughput. Such a system is able to optimize the order of stops and thereby save energy while enhancing the individual's sensation of efficiency. Other examples are electronic awareness-systems which can track people in the building and automatically turn on and off lighting and heat, and adaptive door signs. This can be achieved by deploying sensors of different kinds (such as photo sensors, proximity sensors, and cameras) and interpreting the sensor data received. Further examples can be emergency lights embedded in the floor which show the way to the nearest exit. These can also be used to lead guests to specific offices.

Apart from that, modern buildings can learn, i.e., they can collect data and thereby extrapolate or predict human behavior. This is helpful in order to recognize situations out of the ordinary (e.g., intruders or even people in trouble) as well as prepare for predicted excessive demands like the morning rush of arriving employees to elevators. This paper gives an overview on current trends in building automation for office buildings

Keywords: Building automation, office, energy consumption, occupant comfort, elevator, emergency solutions

1 Introduction

Many office buildings existing today were built several decades ago, obeying the construction rules and laws of these times. There are only few cases where existing buildings have to be refitted or upgraded to new laws (such as the elimination of asbestos, which was banned in several states in the 90’s and in the European Union in 2005). In these cases normally transitional provisions are granted, postponing the mandatory retrofitting for several years. So even today many buildings still have asbestos-containing pipes, roof tiles, thermal insulation, plasterwork, etc.

[1] Institute of Computer Engineering, Universität zu Lübeck, Ratzeburger Allee 160, D-23562 Lübeck, haase@iti.uni-luebeck.de

[2] Faculty of Electrical Engineering, Helmut Schmidt University of the Federal Armed Forces Hamburg, Holstenhofweg 85, D-22043 Hamburg, dmeyer@hsu-hh.de

Apart from avoiding health threats, many newer trends find their way into refurbished or newly built buildings. These more and more include comfort features for the inhabitants or – in the case of public buildings – employees and visitors.

Section 2 gives an overview on currently existing requirements (by law or by trend) for modern buildings. Section 3 highlights several use cases. In Section 4 open questions and future topics are touched, before Section 5 concludes this paper.

2 Requirements for Modern Buildings

The current requirements for newly built or refurbished office buildings can be categorized into the following classes:

- Safety
- Security
- Comfort
- Energy saving

2.1 Safety

Safety aspects encompass all parts of office buildings where accidents might happen. This includes disasters like fires, earthquakes, etc. Thus, buildings have to be designed to not trap fleeing people, with a special attention on the needs of the elderly or disabled.

2.2 Security

In this category all parts of surveillance and counteractions against theft or breaking and entering are located.

2.3 Comfort

People working in public buildings are nowadays used to certain comfort features such as escalators, elevators (possibly with a higher capacity due to special control schemes), smooth and quiet floors, doors automatically opening using motion detectors, etc.

2.4 Energy saving

This category has become more and more important in the last years due to efforts to lower the overall energy consumption of office buildings. This covers thermal insulation as well as distributed low-power sensors. These sensors nowadays use ultra-low power communication protocols like ZigBee or Wireless Hart [GHG11] in order to save energy and are in many cases equipped with harvesting features like small solar panels.

Various adaptable systems and devices including photovoltaics, batteries and electric vehicles have been proposed for the purpose of supporting highly energy sustainable buildings as well as enhancing overall comfort for the people residing or working in it [HZA15].

3 Selected Use Cases

In this Section a number of selected use cases is highlighted which shows the current state of the art regarding the categories described in Section 2.

3.1 Elevators

The first elevators were used for centuries for goods only, but in the second half of the 19th century the triumph of passenger elevators started with the introduction of the safety elevator by Elisha Graves Otis in 1852. This elevator featured a mechanic brake in case the rope the elevator was hanging from broke.

In the next decades the availability of elevators enabled master-builders to design houses much higher than four or five floors which was common until then. This was an important pre-condition for the construction of skyscrapers in the 20th and 21st century.

Nowadays, essentially all office buildings have elevators, but an important issue is the footprint, i.e., how much space it will consume. Furthermore, common elevators cannot be used as an emergency route in case of a fire in the building due to smoke and electrical shutdown; thus, saving elderly or disabled people from higher floors the fire truck's ladder cannot reach is a serious problem. Furthermore, the throughput of elevator systems in terms of passengers/time unit is being maximized, since especially in peak times often long queues of waiting passengers form in front of the elevators. These problems are being addressed by more recent technological developments.

As elevators often present to be a bottleneck for passengers, several approaches were developed to address this problem. Typically, many passengers want to travel from the ground floor to one of the upper floors in the morning, and back down again in the evening. An easy adaption of common elevators is the feature that the cabins wait with closed doors and thus can quickly be sent to any floor they are requested to. Better algorithms [BR15] also send them back automatically to the ground floor in the mornings, even if they are not currently being requested. The traffic patterns can be categorized into peak traffic, down peak traffic, lunch time (two way) traffic and inter-floor traffic [SC10].

A technologically new step was the double deck elevator, which was first installed in the Eiffel Tower in Paris 1889 and then in the Empire State Building 1931 by Otis but is still not very common today. The idea is to have one cabin stop at even floors and the other at odd floors and thus transport twice as many passengers at the same time. Depending on their destination, passengers can take an escalator to a landing of the alternate cabin (see Fig. 1).

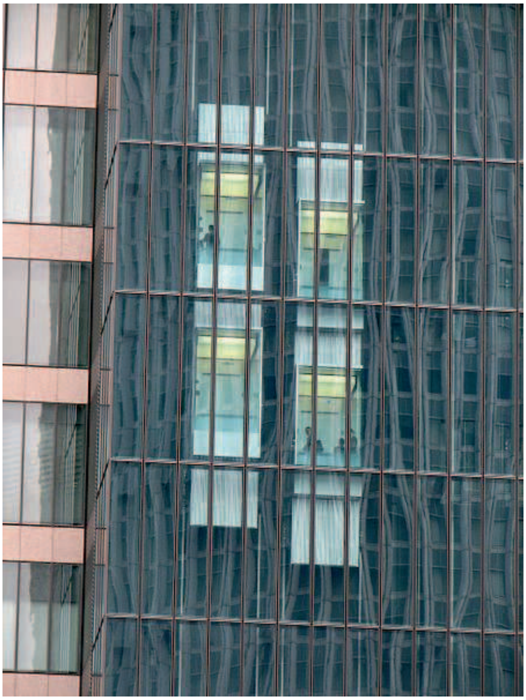


Fig 1: Double elevator at Midland Square Nagoya, Japan (taken from [WC16])

Modern elevators may feature a regenerative drive (see Fig. 2), i.e., they feed energy generated when the cabins slow down back to the building's power grid. The difference between the lightly or heavily loaded car and the counterweight is used to harvest energy – a concept being used for modern trains, too, which harvest energy when slowing down before stops at train stations. The overall energy consumption of the elevator can thereby decrease by 30% [HZZ14,LSC15].

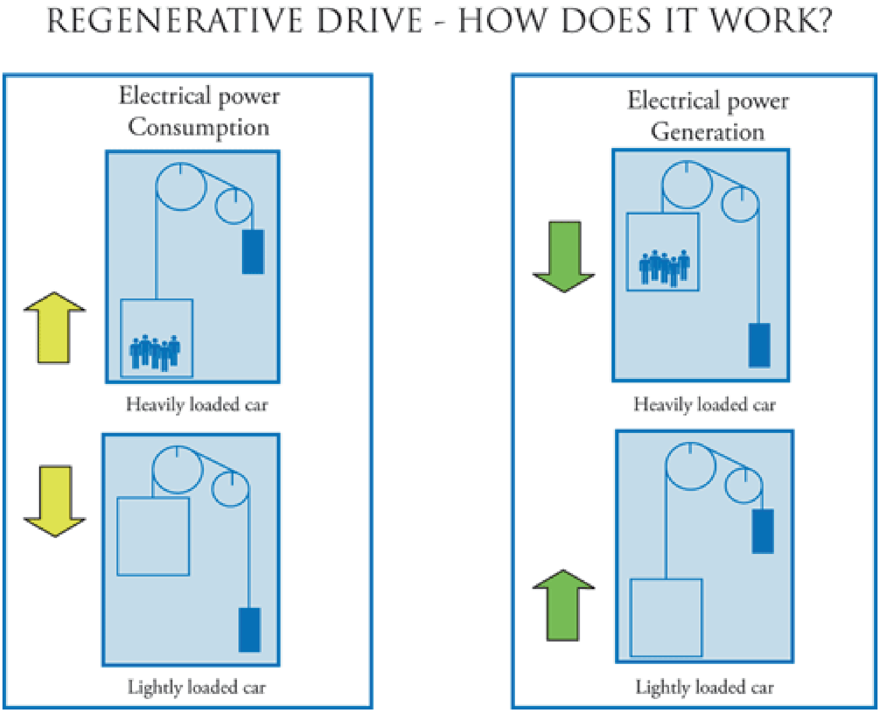
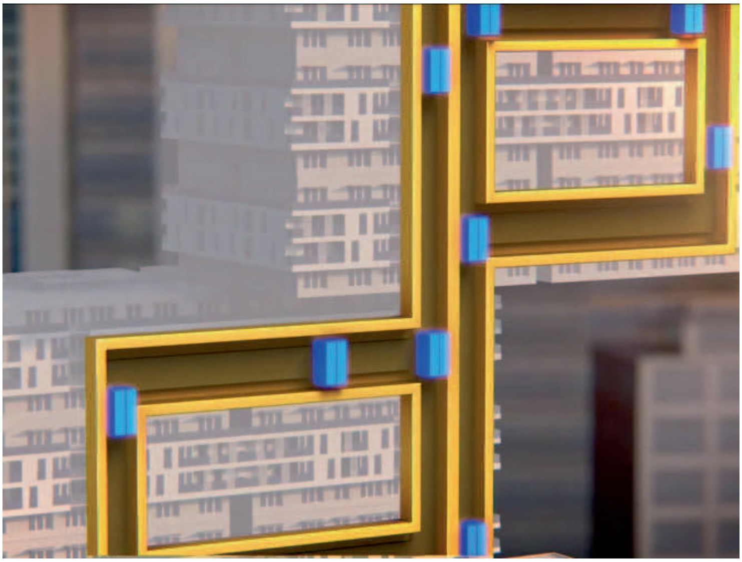


Fig 2: Regenerative drive (taken from [Otis16])

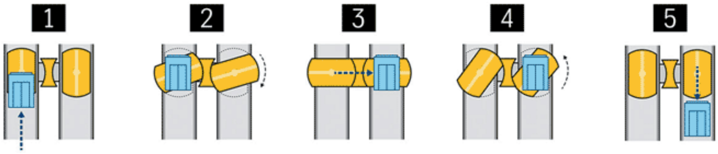
An important new concept invented by ThyssenKrupp in 2003 was the Twin [Thy03]. It runs two cabins in the same elevator shaft, one above the other. The selection of target floors is not done in the cabin, but outside, and therefore the scheduling algorithm can send the better suited cabin to pick up the passenger. The scheduling control also avoids collisions. ThyssenKrupp indicates time saving of about 65%.

A very new and unique approach is ThyssenKrupp's Multi [Thy16a]. It runs cabins without ropes or cables. The engines are not located in an elevator engine room, but in the cabins itself. Thus the cabins can run independently from each other and not only move vertically, but also horizontally (if horizontal shafts exist). This enables the cabins to reach different parts of buildings as well as pass each other (see Fig. 3). A test tower presenting the first implementation of this technology is currently being built in Rottweil, Germany, and expected to be finished by end of 2016 [Thy16b].

The MULTI system and possible competitor products will then open up new ways of elevators, since in case of higher demand simply some additional cabins can be put into operation, and put aside when demand decreases.



(a)



(b)

Fig 3: The MULTI system: (a) cabins running independently and even horizontally, (b) an elevator changing from one vertical shaft to another (both taken from [Thy16a])

Other studies try to conserve energy and enhance comfort by estimating the number of passengers in a common elevator by means of cameras [MIY15]. The idea is to reduce unnecessary stops for full elevators.

One of the solutions for the safety problem of rescuing people from higher floors in case of disasters like fire is the evacuation elevator [JD07, KOK14]. It offers continued operation using auxiliary energy and is built in a way that on all floors a certain area in front of the elevator can be sealed off by fire doors, forming a safe location for disabled people. The evacuation elevator can then be boarded and will take all passengers to the ground floor.

3.2 Lighting and Heat

If the building control system has information about where people are currently present, a lot of energy can be saved by only activating heat in non-empty rooms. Unused offices thus don't consume energy above the minimum [MHR14, ANC15, ADH16].

This also may enhance the comfort of occupants. However, the estimation of comfort parameters is a complex problem [RFR15, SCP15].

In the last years, the topic of automatic ventilation and shading (by sun tracking or shadow outline tracking) was well covered by industry. The idea is to keep out heat in warm regions or summer times while letting in light, avoiding artificial lighting in the day for power consumption reasons. Special kinds of glass shades can be attached to the building surface and automatically rotated depending on the solar factor [Colt15].

Furthermore, long corridors can be (automatically) lighted only where people are, further decreasing overall energy consumption.

Buildings – and particularly public buildings – are viewed as possible objects for storing energy. The idea is to slightly overheat in times of cheaper energy and thus having to heat less later, when the price of energy has risen over the day. Furthermore, solar energy is to be stored, too. Similarly, cooling of buildings in hot regions or summer times can be made more energy-efficient this way. Current projects try to forecast the energy availability as well as the energy consumption [PZJ11, YCZ12, SUT13, KZ15].

3.3 Tracking People

In office buildings it might be convenient to track people. There are several possible reasons. In order to save energy, lighting and heat might only be switched on (possibly automatically) when people are present, as described in the previous Section. Typical technologies for tracking are motion sensors, evaluation of employees' access cards, cameras recognizing and tracking faces [LLZ15], or wearable devices [HRT14].

Apart from that an information about the whereabouts of people in a building is very helpful in a case of emergency like a fire or earthquake. The rescuing team (e.g., firemen) can then focus on rooms with (possibly incapacitated or unconscious) persons and ignore empty offices.

However, the gathering of data to get this information is legally problematic in many countries – it violates the security rights of the people being monitored. There are still open issues in terms of finding a viable path between emergency preparation and data privacy protection [GH89].

3.4 Security Features

A very common security application in office buildings is access control.

Currently, the usual access control systems (see Fig. 4) are more and more being replaced by smarter systems which have intelligent readers. Other studies focus on fully automated face recognition systems [IZ11] instead of relying on tracking data (see Section 3.3).

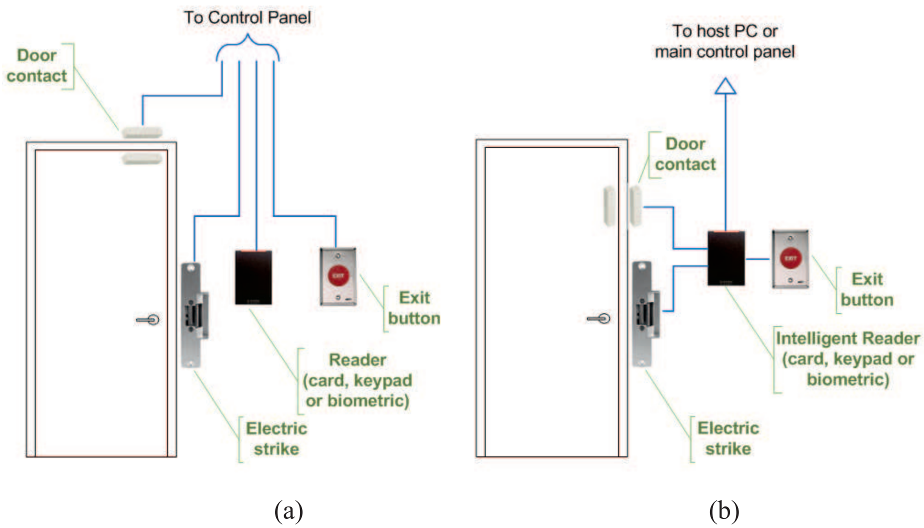


Fig. 4: Typical door access control. (a) basic readers send read or detected data to a control panel which then in turns decides whether the door is to be opened, (b) intelligent readers can directly control the door opening

3.5 Emergency Solutions

Modern office buildings feature several approaches to lessen the impact of disasters like fire or earthquakes. Typical examples for this are non-flammable floors and wallpapers, emergency lighting in case of a power failure, or windows being opened automatically in case of fire which act as smoke outlets.

Other approaches focus on the rescue team (e.g., the firemen), who have to enter the burning building and quickly save people as well as extinct the fire. Current office buildings do have a floor plan available for firemen which indicates all relevant locations like hose couplings or dangerous fuel tanks.

This might in the future be enhanced to include more or less current data about the people present in the building (see Section 3.3). Furthermore, currently blocked areas can be marked in the floor plan. This requires an adaptable or even interactive presentation, e.g., a floor plan on a fireman’s tablet pc instead of an ordinary printout.

Taking a step further, this floor plan with additional information could be loaded into standardized (and thereby widely available) display systems of fireman’s masks, giving them an augmented reality view, similar to Google’s glass (see Fig. 5) or other wearable computers [Bar16].

The office building control system needs to unlock doors for rescue teams in order to offer the most direct way to trapped victims. This is a feature not yet widely implemented.

Fig. 5: Augmented reality for firemen using Google Glass (taken from [FG14])

4 Future Topics

Future topics for elevator technologies will be the ever increasing number of passengers due to higher and bigger buildings. Particularly office buildings tend to be located in city centers, where land prices are steep – thus they will almost certainly be built higher and higher. If the passenger queues cannot be processed in time, though, the value of upper-floor offices (and apartments) will decrease. Thus this is still an open problem. The new approach of independently running cabins also gives the opportunity to create "premium" services for special guest, i.e., cabins reserved for important passengers which will then be given priority on their way to the destination.

Another future topic might be to use lighting in the floor or walls as a guidance system for guests or visitors, leading them to the exact office they need to be. If the employee the visitor has an appointment with currently stays in another room (e.g., a conference room), the guidance system automatically adapts and shows the quickest route.

Future security related topics could be focusing on the electronic desktop. Currently, it is already possible in many offices to log in at any computer and access personal data from there, as it is stored on a central server. In the future, all office equipment might be connected this way and thus also incoming phone calls might automatically be rerouted to the room an employee currently is in, door plates adapt according to the current occupants of a room (which might be even more useful for conference rooms), and even personal comfort data like preferred room temperatures is migrated with the employee. All these features can also extended to home office via secure VPNs.

Furthermore, new algorithms using face recognition or similar methods could make use of tracking data and check the plausibility of results, e.g., if an employee was detected and identified in the lobby seconds ago and now wants to enter a restricted room. If these algorithms are adequately reliable, future offices might get on without access cards or entry codes at all.

The area of emergency management is a growing topic for public buildings. An important subject is the automated communication with rescuing teams entering the building. For this, new protocols might be needed. Other communication, suddenly of much lower priority, be choked off – an example might be a massively used WiFi network which will automatically disconnect all clients in case of an emergency in order to minimize traffic and keep enough bandwidth for emergency communication. Furthermore, the guidance system for visitors mentioned before could be used for rescuing teams, too, showing the quickest way to a given destination.

5 Conclusion

This paper gave an overview on current developments in the area of building automation with regard to office buildings. Due to the longevity of public buildings the spectrum of buildings with more or less modern features is large; usually only in case of newly built or refurbished buildings new technology is introduced. However, there are several interesting approaches that might become trendy or even compulsory in the years to come for existing buildings.

6 References

[ADH16] I. B. A. Ang, F. Dilys Salim and M. Hamilton, "Human occupancy recognition with multivariate ambient sensors," 2016 IEEE International Conference on Pervasive Computing and Communication Workshops (PerCom Workshops), Sydney, NSW, 2016, pp. 1-6.

[ANC15] A. Akbar, M. Nati, F. Carrez and K. Moessner, "Contextual occupancy detection for smart office by pattern recognition of electricity consumption data," 2015 IEEE International Conference on Communications (ICC), London, 2015, pp. 561-566.

[Bar16] Woodrow Barfield, Ed., "Fundamentals of Wearable Computers and Augmented Reality", 2nd Ed., CRC Press, 2016, ISBN 978-1-4822-4351-2

[BR15] D. T. Bamunuarachchi and D. N. Ranasinghe, "Elevator group optimization in a smart building," 2015 IEEE 10th International Conference on Industrial and Information Systems (ICIIS), Peradeniya, 2015, pp. 71-76.

[Colt15] Colt International Ltd., "Shadoglass and Shadovoltaic Solar Shading Systems", 2015, http://www.colt.es/descargas.html?file=tl_files/pdf/Solar%20Shading/Shadoglass%20and%20Shadovoltaic%20solar%20shading%20systems.pdf

[FC14] Fast Company, "This Firefighter Built His Own Google Glass App And It's Saving Lives", 2014, http://www.fastcompany.com/3026559/this-firefighter-built-his-own-google-glass-app-and-its-saving-lives

[GH89] Grant, R. and Higgins, C. (1989), Monitoring service workers via computer: The effect on employees, productivity, and service. Natl. Prod. Rev., 8: 101–112. doi: 10.1002/npr.4040080203

[GHG11] K. Gravogl, J. Haase, C. Grimm, "Choosing the best wireless protocol for typical applications", Proceedings of 24th International Conference of Architecture in Computing Systems (ARCS), 2011

[HRT14] M. Hardegger, D. Roggen, G. Tröster, "3D ActionSLAM: wearable person tracking in multi-floor environments", Journal of Personal and Ubiquitous Computing, Vol. 19, No. 1, pp. 123-144, Sept 2014, ISSN 1617-4917

[HZA15] J. Haase, G. Zucker, F. AlJuheshi, M. khair Allah and M. Alahmad, "A survey of adaptive systems supporting green energy in the built environment," Industrial Electronics Society, IECON 2015 - 41st Annual Conference of the IEEE, Yokohama, 2015, pp. 004009-004014.

[HZZ14] J. Han, Z. Zheng, J. Zheng and J. Li, "A survey of braking energy recovery and management technology," Transportation Electrification Asia-Pacific (ITEC Asia-Pacific), 2014 IEEE Conference and Expo, Beijing, 2014, pp. 1-4.

[IZ11] R. Ibrahim and Z. M. Zin, "Study of automated face recognition system for office door access control application," Communication Software and Networks (ICCSN), 2011 IEEE 3rd International Conference on, Xi'an, 2011, pp. 132-136.

[JD07] Theodore L. Jarboe, John O'Donoghue, "Elevator and Escalator Rescue, a Comprehensive Guide", PennWell, 2007

[KOK14] Max T. Kinateder, Hidemi Omori, Erica D. Kuligowski, "The Use of Elevators for Evacuation in Fire Emergencies in International Buildings", National Institute of Standards and Technology, NIST Technical Note 1825, July 2014, http://dx.doi.org/10.6028/NIST.TN.1825

[KZ15] K. J. Kircher and K. M. Zhang, "Model predictive control of thermal storage for demand response," 2015 American Control Conference (ACC), Chicago, IL, 2015, pp. 956-961.

[LLZ15] Jun Liu, Ye Liu, Guyue Zhang, Peiru Zhu, Yan Qiu Chen, "Detecting and tracking people in real time with RGB-D camera", Pattern Recognition Letters, Volume 53, 1 February 2015, Pages 16-23, ISSN 0167-8655, [LSC15] S. Lin, W. Song, Y. Chen, L. Luo and Z. Feng, "Study on the model of elevator regeneration energy and its energy storage control method," 2015 International Conference on Smart Grid and Clean Energy Technologies (ICSGCE), Offenburg, 2015, pp. 125-128.

[MHG10] J. M. Molina, J. Haase and C. Grimm, "Energy Consumption Estimation and Profiling in Wireless Sensor Networks," Architecture of Computing Systems (ARCS), 2010 23rd International Conference on, Hannover, Germany, 2010, pp. 1-6.

[MHR14] N. Masoudifar, A. Hammad and M. Rezaee, "Monitoring occupancy and office equipment energy consumption using real-time location system and wireless energy meters," Proceedings of the Winter Simulation Conference 2014, Savanah, GA, 2014, pp. 1108-1119.

[MIY15] F. Mohamudally, C. S. Inn, L. S. Yeong and C. W. Chong, "Estimating free space in an elevator's confined environment," TENCON 2015 - 2015 IEEE Region 10 Conference, Macao, 2015, pp. 1-6.

[Otis16] Otis Elevator Company, Website, http://www.otis.com, 2016.

[PZJ11] P. Palensky et al., "Demand response with functional buildings using simplified process models," IECON 2011 - 37th Annual Conference on IEEE Industrial Electronics Society, Melbourne, VIC, 2011, pp. 3230-3235.

[RFR15] M. L. Ruz, S. Fragoso, D. Rodríguez and F. Vázquez, "Real-time estimation of thermal comfort indices in an office building with a solar powered HVAC system," Control and Automation (MED), 2015 23th Mediterranean Conference on, Torremolinos, 2015, pp. 803-808.

[SC10] George R. Strakosch, Robert S. Caporale, Eds., "The Vertical Transportation Handbook", 4th Ed., Wiley, 2010, ISBN: 978-0-470-40413-3

[SCP15] S. S. Shetty, H. D. Chinh and S. K. Panda, "Strategies for thermal comfort improvement and energy savings in existing office buildings using occupant feedback," 2015 IEEE International Conference on Building Efficiency and Sustainable Technologies, Singapore, 2015,

[SUT13] L. Spitalny, D. Unger, J. Teuwsen, V. Liebenau, J. M. A. Myrzik and B. Van Reeth, "Effectiveness of a building energy management system for the integration of net zero energy buildings into the grid and for providing tertiary control reserve," PowerTech (POWERTECH), 2013 IEEE Grenoble, Grenoble, 2013, pp. 1-6.

[Thy03] ThyssenKrupp, TWIN elevator system, https://twin.thyssenkrupp-elevator.com/, 2003

[Thy16a] ThyssenKrupp, "MULTI, a new era of elevators to revolutionize high-rise and mid-rise constructions", http://www.thyssenkrupp-aufzuege.de/en/new-installation/elevators/pass
enger-elevators/multi/, 2016

[Thy16b] ThyssenKrupp, "The Test Tower, starting point of ground-breaking projects", http://testturm.thyssenkrupp-elevator.com/en/, 2016

[WC16] Wikimedia Commons, https://en.wikipedia.org/wiki/File:Double_elevator_at_Midland_
Square_Nagoya.JPG, 2016

[YCZ12] Xiaohui Yan, Haisheng Chen, Xuehui Zhang and Chunqing Tan, "Energy storage sizing for office buildings based on short-term load forecasting," 2012 IEEE 6th International Conference on Information and Automation for Sustainability, Beijing, 2012, pp. 290-295.