

The Use of Lifts in Offices in Social Distancing Environments

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Abstract. This paper addresses the potential remaining lift capacity for high-rise office buildings when limiting the number of passengers per car to only two persons due to social distancing restrictions in the COVID-19 era. It describes an array of measures that have to be taken to guarantee personal safety and sufficient distance, namely by eliminating crossing traffic and optimising the potential use of the lift system. Both the waiting time and the lobby capacity can be decisive when searching for the optimum. Without proper measures only about 20-30% of the original population can usually be served. With major measures and by successfully reducing peak flows the new maximum population can be increased to about 40-60% of the original population.

1 INTRODUCTION

In the spring of 2020 most office buildings were temporarily abandoned due to national lockdowns as a result of the global outbreak of the COVID-19 virus. To avoid further spreading in crowded working environments the majority of office workers have since then been working from home and have not been able to visit their offices on a daily basis. Since the summer of 2020 most countries have gradually released the restrictions for outside activities but still hold back on indoor activities with large densities of people in areas with possibly insufficient ventilation capacity. In most public buildings social distancing of 1.5-2.0 m between individuals must be maintained and most companies transfer these restrictions to their office environment to minimise the risk of an outbreak in their personnel. Apart from the significant reduction in floor capacity in terms of usable desks the social distancing rules also reduce the practical capacity of lifts, stairs, corridors and lobbies. This paper offers an overview of the outcome of several lift studies that were performed for existing office buildings to determine the limitations and points of attention due to social distancing in lifts and lift lobbies.

2 POPULATION

The outcome of several building studies shows that social distancing restrictions in offices can result in a significant reduction of available desks and supporting services. The population that can actually return to work safely within the new settings appears to be in a range of 50%-65% of the original population, depending on the offices type, the lay-out of the building and its floors and the original office floor density. The higher the original density of desks per floor area was (one desk per 6-8 m² net floor area is not uncommon in open-plan offices nowadays), the higher the density reduction factor will be. The number depends very much on the lay-out and orientation of the desk clusters per floor: how many desks per cluster can be used safely, can these clusters be moved or rearranged to provide more distance, are there any corners of the office area that have to be closed off to avoid deadlocks and facilitate one-way traffic flows? It also depends highly on how far the owner/employer is willing to invest to alter the lay-out temporarily and provide safety measures such as protective screens and organise additional cleaning/disinfecting service rounds. Additionally, in some cases the lay-out of general services such as restaurants, toilet areas, cloakrooms and pantries provide a maximum on a floor or even building scale on top of the local limitations. Reduced availability of stairwells might limit the population due to safety implications in case of evacuation. And then there is the issue of the remaining lift capacity, that reduces the maximum returning population even further.

3 LIFT AND LOBBY CAPACITY

There are two main reasons why the transportation capacity of the original lift system will decrease significantly in a social distancing office environment:

- Reduction of the maximum car load to no more than 2-3 persons per car, thus reducing the fundamental transportation capacity of the lift system;
- Reduction of the lobby capacity for waiting persons due to loss of maximum density and/or loss of waiting area due to newly required traffic corridors.

Compared to the regular car loading in common 1,275 – 1,800 kg lifts in office buildings the loss of capacity in a lift car due to social distancing can be up to 75-90%. This is a huge decrease of transportation capacity from the original design. Luckily there are mitigating circumstances that improve the potential significantly, such as lower cycle times and less interference from two-directional and interfloor traffic. Please refer to sections 4-6 for a further substantiation of this effect.

Regarding the lift lobby the common area capacity will typically reduce from a range between approximately 0,5 m² (crush capacity) and 0,75 m² (normal capacity) per person under normal conditions to a range between approximately 2,5 m² (no cross traffic) to 3,0 m² (limited cross flow) per waiting person under social distancing conditions. This too is a reduction in capacity of 70-85%. These values already take into account that several corners of the area will not be used efficiently.

The loss in waiting capacity will be urgently noticeable through the forming of significantly longer queues than normal. The loss of transportation capacity will add to the problem indirectly by processing significantly less people per time unit than previously. The combined effect will result in huge levels of congestion in the waiting areas and corridors leading up to these areas, if the original population were to be given access to the building. This is exactly what needs to be avoided in a social distancing environment and that is why the visiting population has to be reduced to restore balance in the system for buildings that rely heavily in the lift system.

The limitations mentioned above force us to reconsider both the conventional traffic handling capacity of the lift configuration - based on (increased) waiting time criteria - and the available lobby area – considering the required (decreased) queue lengths potential. Both capacities can be the limiting factor in social distancing lift analyses.

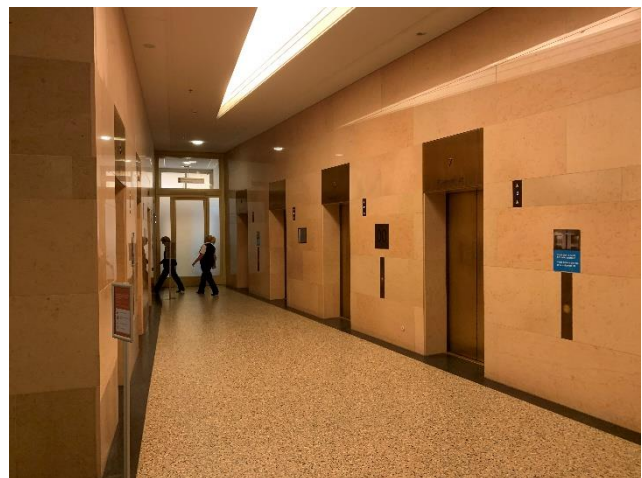


Figure 1: Empty lift lobbies during the COVID-19 period. Will they soon fill up again with reduced queuing density?

4 PRIMARY MEASURES (HOW TO BOOST POTENTIAL)

For boosting the remaining traffic handling capacity in office buildings to allow a population as high as possible to safely return to the building, the following (mainly organisational) measures should be considered:

- **Increasing the use of stairs:** Mandatory use of stairs for the bottom 3-5 floors should be introduced, assuming that proper solutions for the transportation of mobility impaired persons (MIP) and goods are available (see below). The stairs should be used in one direction only, unless they are at least 2 meters wide or can be divided into an upward and a downward lane by temporary screens. This is necessary to guarantee safe distance between the people using it: passing each other will usually not be possible within normal stairs width. Additionally some stairs may have to be closed off completely (for instance if they exit into the lift lobby thus jeopardizing the main traffic flow) or made accessible in one direction only;
- **Eliminating interfloor traffic:** If possible within single tenant situations (or multi-tenant with multiple floors per tenant) interfloor traffic in the lifts should be eliminated as much as possible. This means that the use of stairs between floors becomes mandatory. This measure is necessary to keep the cycle time of the lifts for primary home floor traffic as low as possible, and to prevent stops with already filled cars when conventional controls without a (modifiable) car weighing device are present. Please refer to section 5 for a further explanation;
- **Reducing and spreading meeting traffic:** It will remain important to meet online as much as possible, due to the reduced capacity of meeting rooms and to avoid hourly meeting traffic peaks. It is vital to avoid unnecessary interfloor traffic peaks on the whole hours. This can be solved by making sure that half of the meeting facilities can only be booked on the whole hours and the other half only on the half hours. This results in a halving of the internal meeting peaks. The alternating schedule can be realized by programming 30 minute disinfection breaks in between the meetings;
- **Avoiding crossing traffic flows:** Crossing flows in the lift lobbies should be avoided as much as possible, to maximise floor area and prevent door transfer time delays due to people waiting for counterflow traffic. This is necessary to avoid dense flows in two directions through a common lobby, resulting in a major reduction of waiting area capacity and or risk of a breach in the safety distancing between people. This may require eliminating the lunch peak traffic, providing separate floors for incoming and outgoing traffic and opening/closing secondary entrances:
 - **Eliminating lunch peak traffic:** Lunch traffic does not only burden lift group controllers the most these days, it also results in unwanted two-way traffic in lobbies. It is advisable to consider eliminating two-way lunch traffic as a whole by introducing mandatory lunch in the workplace, unless incoming traffic and outgoing traffic can be vertically separated (see below). So preferably the restaurant(s) and any other decentralised facilities (coffee corners and take-away points) should be closed off. If necessary, lunch boxes can be delivered on the office floors in the morning with a separate goods lift;
 - **Vertically separating incoming and outgoing traffic lobbies:** If the incoming and outgoing traffic during lunch break can be vertically separated on different levels, two lobbies (one for incoming and one for outgoing traffic) should be used. Lunch traffic will then however remain dominant for the analysis and the achievable remaining population. A benefit here is that the lobby capacity will probably not be the limiting factor anymore. On the other hand, traffic between the two separated floors will not be possible, so alternative measures for MIP and goods traffic might be necessary. The separation can be advantageous for the morning up peak and the afternoon down peak as well, since no counter traffic routes have to be organised in the main lobbies;

population. This reduction should preferably be realised by closing off the highest floor(s). For office buildings with 10 or more floors above the ground floor a significant reduction of the visiting population and/or populated floors will be necessary to guarantee safe working and traveling conditions for the population. These buildings require bespoke analysing of the traffic handling with the available lift and lobby system.

5 SECONDARY MEASURES (HOW TO MAKE IT WORK)

The following secondary measures will probably be required to guarantee safe use of the lifts from a social distancing perspective and make the processes as described in section 4 work properly:

- **Reducing the car load:** Reduction of the maximum car load to 2-3 people through adjusting the load bypass thresholds (when using a weighing device with conventional controls) and/or the controller settings (when using destination control) will be necessary. For upwards traffic from the main lobbies this can also be organised by emphasising and upholding the limited car loading rules to the users, but especially for downwards traffic it is crucial that the car load is limited to 2-3 persons to avoid unnecessary stops, resulting in loss of capacity and irritation for the users. When using destination control this can be done from within the intelligent control system, but if there is a conventional control system this will not always be possible. A load weighing device with a load bypass system will not always be available and if there is one it is not self-evident that it can be adjusted to function properly and reliably in the 150-225 kg range. Possibly a (costly and time consuming) modification of the car and counterweight balancing or other sensing devices (infrared detection) are required. If this is not addressed, interfloor traffic and/or the otherwise rather harmless afternoon down peak could become dominant in the capacity and quality experience of the users due to a series of unnecessary and frustrating stops. In these rare cases down traffic should be forced to use the stairs or concentrate on transfer levels to be collected by lifts with dedicated service zones;
- **Identifying waiting zones on the floor:** Although it would be best to rely on the discipline and common sense of the population, it is recommended to provide visual reference areas or waiting spots on the floor in the main lobbies (mandatory guidance). On the upper floors the density in the lift lobbies will be minimal and personal discipline will be sufficient;
- **Improve circulation and guarantee safety distances:** Within small lobbies and especially when two-way traffic or through traffic in the lobbies is unavoidable, mandatory routing and safe zones should be provided by using screens to separate the waiting areas (with circles or 1.5-2.0 m marking on the floor) from the circulation areas;
- **Reducing delays:** The door and sensor delay settings should be improved when they are not already maximized. The chance of extra people embarking late resulting in door re-openings is limited within the new social distancing game rules, assuming the population and traffic is organized professionally and people behave respectfully;
- **Rearranging panels:** Due to conflicting waiting and circulation areas it is possible that hall call panels or destination selection panels (when placed inside the lobby) have to be moved or deactivated if they interfere with the optimal use of the lobby and would introduce more people interacting within social distance limits than strictly necessary. Thus an optimal arrangement of flows versus waiting spots can be achieved in an environment where panel use will be less intense and with a more predictable rhythm;
- **Emphasizing the required discipline and responsible behaviour:** The importance of each person's own responsibility in maintaining a safe distance to others, playing by the rules and behaving respectfully cannot be overemphasized. The same applies to placing one call per person with destination control systems: this becomes even more important than it already was. Everybody shall have to place an individual call, there is no room for ghost passengers.

6 CAPACITY BOOSTING

In section 3 it was stated that the theoretical reduction of traffic handling capacity can be approximately 75-90% of the original capacity due to the limited number of people in the cars. In practice, the remaining values can be significantly better due to the following effects:

- A substantial reduction of lift cycle times due to the fact that the lifts will be making significantly less stops during their cycle and will also have a lower average reversal floor. The reduction depends on the number of floors and the original car loading. For buildings with more than 10 floors and cars with a nominal load of 1,275 – 1,800 kg the number of stops per cycle will typically reduce to approximately only 15-30% of the original number. The average reversal floor will reduce to 70-75% of the original floor height. On the other hand, transfer times will be longer and door sensor times will have to be as well. Please refer to the end of this section for the logic behind this. In the conducted studies so far, the resulting cycle time of lifts with reduced car loading proved to be 20-40% lower;
- There will be a significant reduction in disruptive interfloor traffic, which results in an additional reduction of the cycle times. The effect depends on the tenancy of the building: within a multi-tenant setting the effect will be limited (especially if there are multiple tenants per floor instead of multiple floors per tenant), but in a single tenant situation this effect can provide 5-10% extra traffic handling capacity;
- Due to the above effect the transit times for passengers will be substantially lower and due to that trade-off a rise of waiting times can be acceptable, assuming that the lobby capacity is sufficient. A rise of the average waiting time from for instance 40 to 60 seconds could be acceptable in the new social distancing working culture, if that time loss is earned back during the trip. With appropriate communication about the measures and the procedures the people will understand and accept the new balance;
- If possible, the lunch peak should be eliminated by mandatory lunch breaks on the office destination floors. This eliminates the traffic peak that is dominant nowadays in offices, reducing the traffic handling issue to the lesser challenging morning up peak. This provides room for a more efficient traffic handling of a slightly higher population in the less dense morning traffic profile;
- The traditional peak flow densities in buildings will most likely reduce slightly due to the desire of (a part of) the original population to avoid crowds. Even without mandatory peak flow reduction by for instance introducing fixed time slots for working and lunching hours, it may be expected that morning peak flows reduce from 11-14% per 5 minutes to 9-11% per 5 minutes and lunch peak flows from 12-16% to 10-13% per 5 minutes. The bandwidth is mainly due to differences between single and multi-tenant buildings, locations in the direct vicinity of public transportation hubs and/or lunch facilities that are not on the main entrance floors (resulting in additional lunch traffic between the restaurant and the entrances/exits for people enjoying a lunch break stroll);
- Finally, the new maximum population will probably be significantly lower due to area restrictions for safe working conditions. If the population reduces to the earlier mentioned 50-65% of the original capacity, the remaining traffic handling capacity proportionally increases will approximately 50%-100%.

Depending on the situation in the office tower, two extra measures can be considered to boost the up peak traffic handling compared to the pre-corona situation even more:

- If the lift capacity is dominant: reduce the number of home floors, for instance by closing off stops on basement (parking) levels or podium amenities levels. Be aware that this might be necessary anyway in case there are conventional controls present and the car load weighing device cannot be modified to a 2-3 person threshold;

- If the lobby capacity is dominant: introduce multiple home floors, for instance by allowing basement (parking) traffic or encouraging traffic from podium amenities levels. This requires destination control or a car load weighing device that can be modified to a 2-3 person threshold.

Please be aware that when using lift simulation software to determine the remaining population that can be handled in relation to the lobby capacity there is a potential discrepancy to consider between simulation and reality when using destination control. This is caused by the queuing discipline and organisation, that can be significantly different than usual, for instance when using single line queues (without overtaking possibilities) or split queues (partially in the lobby after the destination control panels and partially outside of the lobby before these panels):

- In case of split queues there will be a lag of information and thus a reduction of the intelligence potential of the lift controller. Within destination control systems the controller can choose to assign people who have arrived later to shortly incoming cars, thus skipping the queue (not First in First Out which is more applicable to conventional traffic handling). This is done to reduce the number of destinations per trip and optimise coincident calls. Within social distancing settings this is not always possible, so the number of selected calls can never exceed the lobby capacity and destinations are possibly given later. In reality the controller will not be aware of the queue that might be present behind the selection panel, in the simulation software it usually does. This results in simulation outcome that are potentially too positive, since the simulation controller knows all the destinations of created agents in advance;
- Even within the lift lobby it might prove to be practically impossible to transfer to an assigned lift through the already waiting people before their lift leaves. This might result in extra delays through efficiency loss (not all spots on the floor will be occupied) and longer embarking times within the lobby.

7 FLATTENING THE CURVES

Apart from the traffic handling and capacity boosting measures presented in sections 4-6 it can also be advantageous to influence the demand side. Corresponding to the global COVID-19 strategy to “*flatten the curve*” to protect health care capacity one could likewise ease the pressure on lift systems by spreading out the demand over longer peak periods. See figure 3 for an illustration. Common peak flow percentages and potential values under social distancing restrictions are:

- Common peak flow values in offices will be between 11-14% per 5 minutes during the up peak and 12-16% per 5 minutes during the lunch peak, depending on a multi- or single tenancy, fixed or flexible working hours and/or direct connections to public transportation hubs;
- Due to the probable reluctance of office workers and hopefully their desire to avoid high densities it can be expected that the population will spread their working and lunch times within the social distancing era more than before. They will probably flatten the curve to possibly 9-11% and 10-13% respectively without the building facility manager having to organize mandatory working shifts to reduce peak values;
- If an even greater reduction of the peak flow density is required in the building to increase the maximum population mandatory working and lunching time slots will be inevitable. Even then a peak of 6-8% and 8-10% during up and lunch peak respectively will probably be the minimum due to other external influences and practical limitations that become dominant. These could be school opening times, public transportation peaks, internal meeting schedules and unavoidable lunch flocking. When mandatory time blocks are introduced for the lunching peak this should not be done per individual floor to avoid congestion in the destination floors lobbies. It would be better to lunch by vertical zone, horizontal zone (North-South or East-

West) or in alphabetical order. This could be slightly disadvantageous for the waiting times, but it prevents undesirable queues in the destination lobbies;

- The outgoing afternoon peak will usually not be relevant in office buildings due to lower peak percentages and scattered traffic in multiple lobbies. There is however one exception if the lifts have conventional controls and a load weighing device is not present or cannot be modified to a 150-225 kg zone with sufficient reliability. In that case the down peak can become dominant after all. Please refer to section 5 for an explanation.

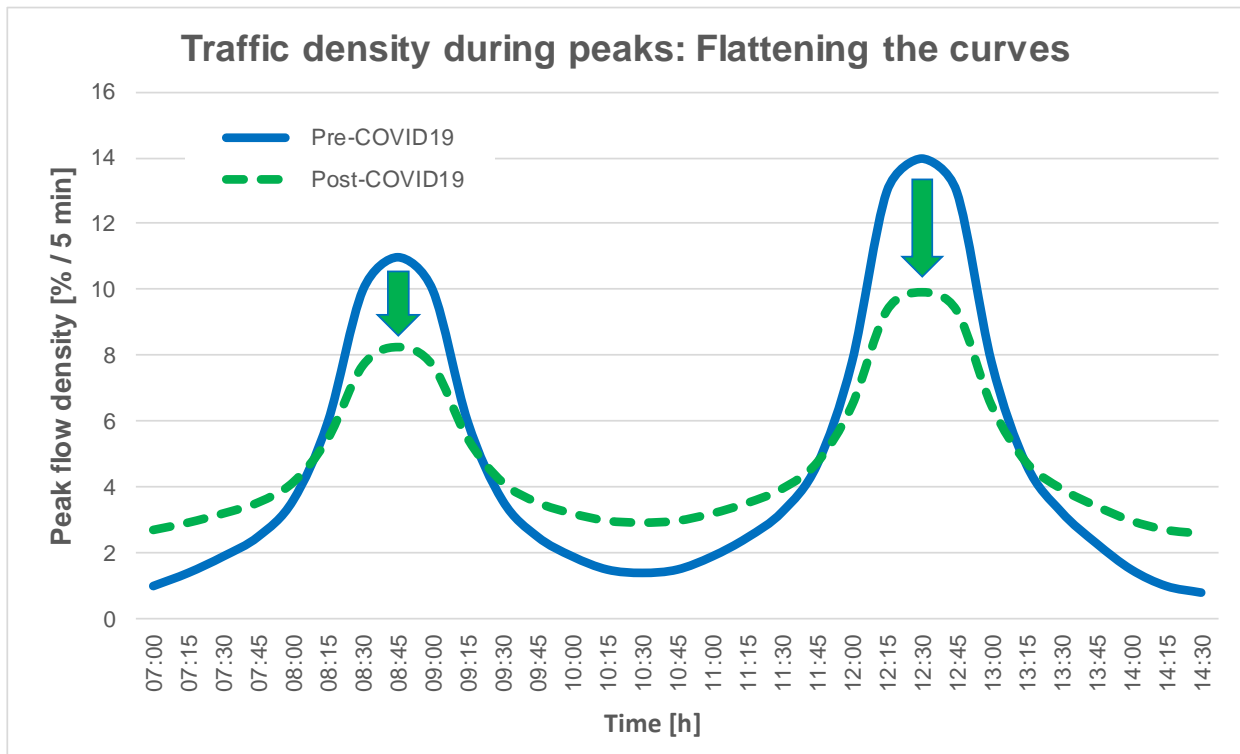


Figure 3: Flattening the curves: Will this happen automatically or does it have to be enforced to optimise lift capacity utilisation?

8 CASE STUDIES

During the COVID-19 pandemic several building studies were performed to determine the potential population that could safely return within social distancing restrictions. Amongst others a national high-rise headquarters and two high-rise ministries asked Deerns to determine how many people could still be allowed in the buildings and how long the queues for the lifts would become, assuming that within social distancing there would only be room for 2 or 3 people in the lifts? They also wanted to know what would be required in terms of organizational measures (traffic flows, use of stairs, peak reduction) and technical measures (lift controls, switching off stops and/or panels, adjusting car loads) to be able to use the building and the lifts safely?

After analysis by means of extensive lift simulations, it has been found that without forced spreading of work times, in most cases about 30-40% of the original population could return to these offices, assuming that the original traffic peaks would slightly reduce due to natural spreading. By moving to forced working time distribution, approximately 40-60% of the original occupation could be welcomed back again. In order to achieve these numbers at the head office the lobby capacity on the ground floor had to be limited to a maximum of 12 people and several destination selection panels had to be switched off. An important additional condition for the re-occupation of this building was that the opposing traffic had to be split during the lunch peak: ascending traffic

will soon leave from the ground floor while descending traffic gets out on the 1st floor and continues down the stairs. In the ministries, the lunch peak will have to be eliminated completely (by providing lunch at the workplace) and the main floor of the high-rise lift groups will be moved to the 2nd floor, in order to make better use of the capacity of the lobby (which will only fit approximately 20 people).

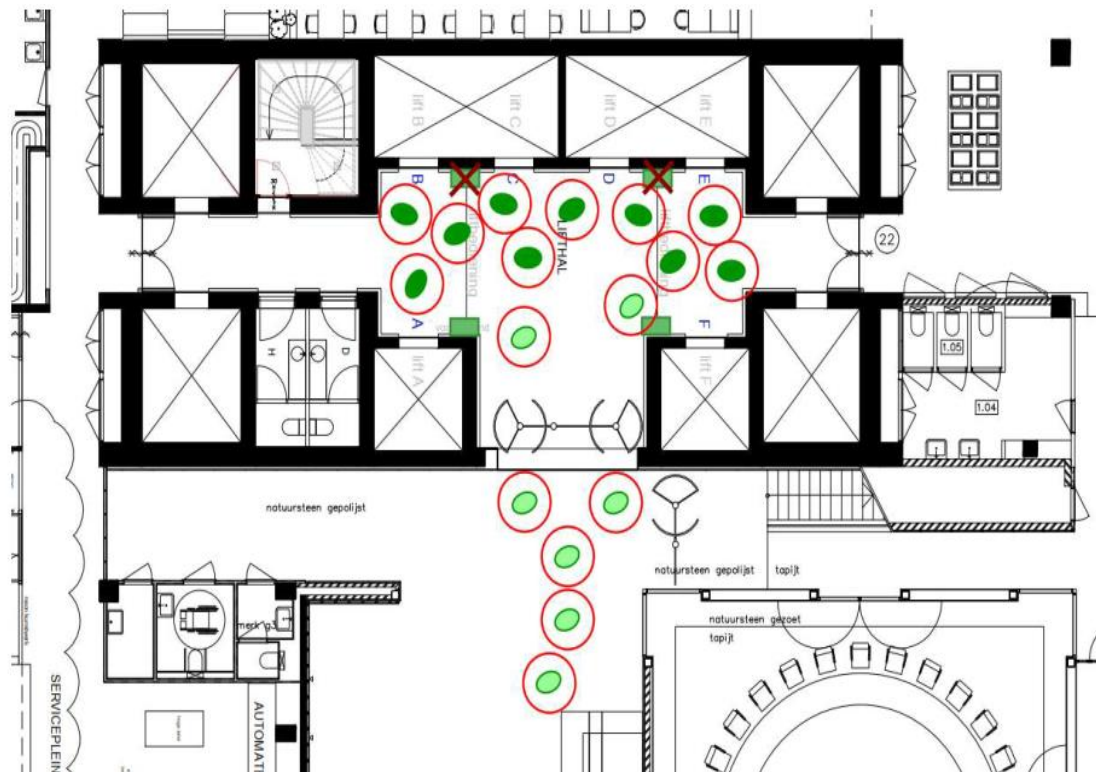


Figure 4: Example of a lift lobby with frontal orientation, a limited number of waiting positions, reduced number of panels and split queues.

From one of these cases figure 4 shows an example of a lift lobby with a remaining queuing capacity of approximately 12 persons, split queues (partially in the lift lobby and partially in the general entrance area) and a reduced number of destination selection panels. In this case lunch traffic had to be vertically split to optimise lobby capacity.

Figure 5 shows an example of a waiting time and queuing length graph, used to determine which of these is dominant for the maximum population to allow back into the building. In this particular case an increased average waiting time value of 50 seconds was acceptable and the remaining traffic handling capacity of the lift group proved to be approximately 22 people per 5 minutes. This traffic intensity would result in an average queue length of approximately 5 persons in the lift lobby, but with stochastic variations up to a maximum value of 14 people. Would the maximum lobby capacity here have been no more than for instance 10 people, the allowed passenger flow should not have exceeded approximately 19 persons per 5 minutes. The corresponding average waiting time would then only be approximately 28 seconds. For reference, this particular lift group would normally provide handling capacity for approximately 50 people per 5 minutes, resulting in a remaining traffic handling capacity of only 38-44% of the original value.

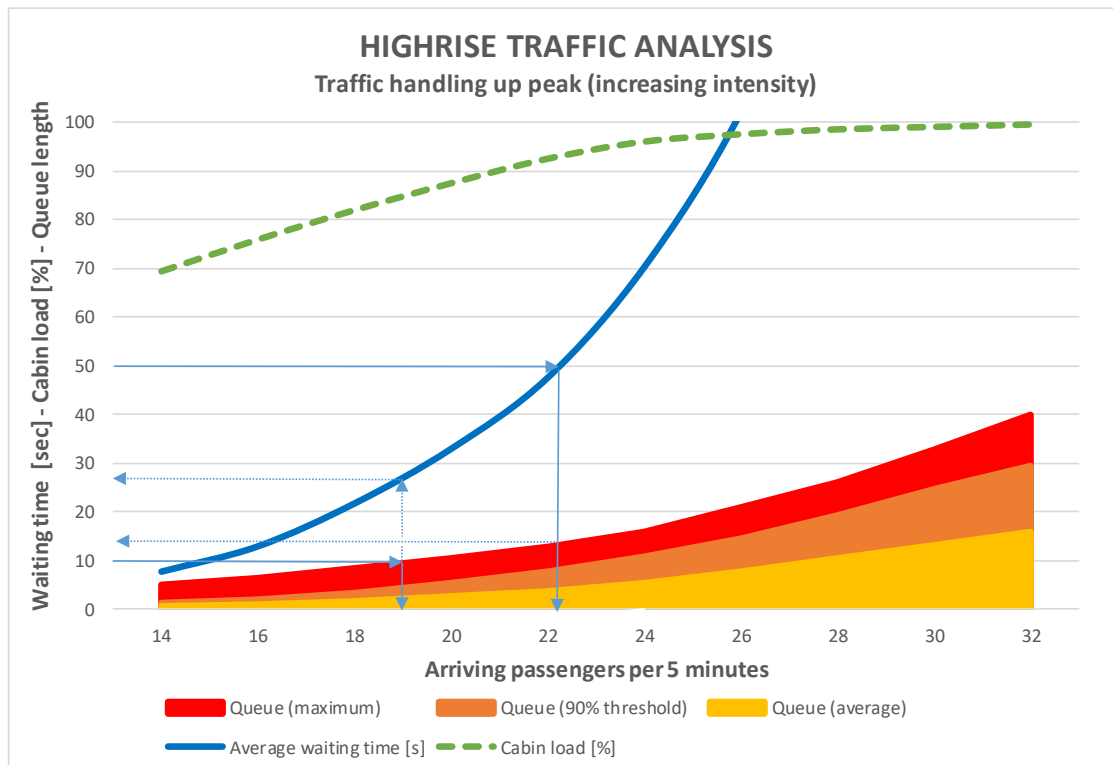


Figure 5: Example graph of a capacity analysis for restricted lift capacity during social distancing (waiting time and queuing length).

9 CONCLUSIONS AND FUTURE PROSPECTS

Analysing the remaining traffic handling capacity and the scope and depth of technical and organisational measures for social distancing lift optimisation is always bespoke work, especially for high-rise buildings. It involves the lift configuration, the building lay-out, the lobby lay-out, the stair configuration, the peak flows, the tenancy (single or multi), the number of home floors and the range of organizational measures the client is willing to accept. For buildings up to about 6-8 floors the lifts are generally not dominant and buildings can generally fill up to their maximum social distancing population when enforcing optimised stair use. For buildings from 8-10 floors above the ground floor the lifts become dominant and the maximum population decreases.

From several practical cases and simulation studies the following main bandwidths were found for traffic handling with reduced car loading in office buildings with 10 or more destination floors:

- Without measures or with only slight adjustments about **20-30%** of the original population can usually be served;
- With major measures (mandatory use of stairs for lower floors and interfloor traffic, no lunch peak or a vertical traffic split for incoming/outgoing lunch traffic, closing off several higher floors, raising the home floor for highrise lifts et cetera) the population can be increased to about **30-40%** of the original population;
- By reducing peak flows through mandatory time schedules for working and lunching hours the population can be increased to about **40-60%** of the original population;
- For most buildings this adds up to about **70-90%** of the newly reduced social distancing population. When a reduction of this revised population is necessary due to the lifts and/or lobby capacity it is best realised by closing off the highest possible floor(s).

The question that remains is if we will soon (if ever) return to the original pre-COVID19 densities of office populations. A permanent higher fraction of workers from home and lower overall densities for offices are very probable in the near future. It is too early to say if we will ever be designing for densities based on 6-10 m² per person again. Will tenants respond by transferring to smaller offices, resulting in more tenants per floor and higher density mixes in existing multi-tenant buildings? A migration of office users to smaller floor plates seems very likely.

To prepare for future circumstances requiring social distancing one might want to consider pandemic proof building designs which provide a fundamental separation between incoming/upward and outgoing/downward traffic. This could require separate stairwells and lift lobbies for incoming and outgoing traffic (vertically stacked) as well as stairwells not directly connected to crowded lift lobbies. This could also have an effect on the required lift lobby area and the need for additional stairs and escalators for splitting inbound and outbound traffic vertically.

These measures could as a side effect increase the lift capacity but also provide more health focus and liveliness in the building, assuming that the stairs connecting to the entrance area are designed to be attractive and wide to accommodate traffic flows at an appropriate distance.

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BIOGRAPHICAL DETAILS

Jochem Wit received his MSc degree in Mechanical Engineering with honours from the Technical University of Delft in 1995. He is a transportation and lift logistics consultant at Deerns. He specialises in lift capacity analyses, simulations and logistical studies for the optimal dimensioning of lift groups in high-rise buildings, complex stacked buildings and hospitals. In recent years he has focussed on evacuation using lifts and solving saturation problems in under lifted / over populated buildings. He works at the Transportation & Logistics department of Deerns, an expert group in the field of building related transportation equipment. Jochem Wit was a member of the Technical Committee of the Dutch High-rise Covenant and chairman of the Technical Subcommittee for Vertical Transportation.

