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Evacuating Using Elevators: Expanding the 2004 CTBUH Approach

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Biography

Jochem Wit received his Master's degree in Mechanical Engineering with honors from the Delft University of Technology in 1995. He is a transportation and elevator logistics consultant at Deerns Consulting Engineers, the largest consultant in the Netherlands for MEP design, sustainability and building management. Wit specializes in elevator capacity analyses, simulations and logistical studies for optimal dimensioning of elevator groups in high-rise buildings, complex stacked buildings and hospitals. He is also team leader of the Transportation & Logistics department at Deerns, an expert group of 10 specialists in the field of building related transportation equipment, like elevators, escalators, travelators, façade maintenance equipment, passenger boarding bridges, automatically guided vehicles et cetera. Since 2007, Jochem Wit is member of the Technical Committee of the Dutch High-rise Covenant and chairman of the Technical Subcommittee for Vertical Transportation. For the development of an elevator evacuation guideline, Wit established an elevator model and technical report for NEN, the Dutch Institute for Codes and Normalization.

Abstract

The Dutch High-rise Covenant is an initiative to develop design guidelines for high-rise towers. It initiated the development of multiple Dutch Technical Agreements (DTA's) to simplify and decrease the lead time of high-rise developing, designing and building. The DTA's include guidelines for vertical transportation in high-rise buildings, one of which deals with the use of elevators for evacuation purposes. This document focuses on a calculation model for evacuation via stairs and elevators combined, as well as on technical and safety requirements for evacuation elevators. It offers several evacuation scenarios and evacuation time estimation models for residential, hotel and office towers. The model is based on the CTBUH publication "Emergency Evacuation Elevator Systems Guideline" (2004) and the traffic handling guideline from the DTA set, but is scaled to the Dutch perspective and enhanced for the following influence factors:

- The optimized traffic handling in evacuation mode;
- The fraction per floor to be evacuated and the stage (zone) to be evacuated;
- The car loading during evacuation and the number of available cars for evacuation.

It also provides an opportunity to compare the performance of several evacuation strategies for high-rise towers and offers simplified equations for refuge floor and shuttle operation when using sky lobbies. Experiments with the model have shown that using elevators and stairs for evacuation simultaneously does significantly reduce the total T_{evac} . Also, the contribution of elevators to a lower combined evacuation time increases as tower height and population density increase. Generally, fractional evacuation is optimal to about 100-150 meters for all the considered building types, for taller buildings refuge floor and free choice evacuation result in a minimal T_{evac} .

Keywords: Elevator, Evacuation, Model, Simulation, Traffic

1 INTRODUCTION

The Dutch national building code only applies to buildings with a maximum building height of 70 meters. Above this height, no strict codes are available, but an equal safety level has to be guaranteed and proven in advance. Subsequently, the approval procedure for Dutch high-rise can be complex and lengthy. To resolve this issue, several high-rise developers, financiers, builders, architects and consultants joined forces in 2006 in the Dutch national High-Rise Covenant. The goal of this covenant was to develop design guidelines for high-rise towers from 70 to 250 meters. Within the High-rise Covenant, multiple Dutch Technical Agreements (DTA's) have been developed to simplify and decrease the lead time of high-rise developing, designing and building. The addressed topics include fire safety engineering, structural design, façades, building installations (HVAC, electrical and plumbing), vertical transportation, sustainability and energy consumption.

Within the vertical transportation subcommittee, DTA's for the following topics have been developed and will be published in Dutch in 2011:

- Evacuation using elevators;
- Elevator traffic handling;
- Elevator ride comfort;
- Elevator functional requirements;
- Elevator energy consumption and recuperation;
- Façade maintenance equipment.

This paper discusses the DTA “Evacuation Using Elevators”, which focuses on evacuation models for combined evacuation using stairs and elevators.



Figure 1: In the current Dutch building codes, there is no mandatory evacuation scenario for wheel chair users

2 THE DTA “EVACUATING USING ELEVATORS”

The research objectives for developing the DTA “Evacuation Using Elevators” are to:

- Determine the optimal evacuation strategy per building type, depending on height and stairs / elevator usage. This model must be usable for non-specialized assessors such as architects, engineers and the fire department;
- Develop a model with which the evacuation time T_{evac} per strategy can be determined;
- Determine how to and when to use elevators for evacuation to lower T_{evac} ;
- Determine the required set of boundary conditions (architectural, structural, fire safety, electrical, organization, communication, elevator execution) for elevator evacuation per strategy;
- Offer a tool for theoretical and strategic planning.

The boundary conditions for using the DTA “Evacuation Using Elevators” are:

- The height of the tower is between 70 and 250 meters (populated floor height);
- The function of the building is office, residential and/or hotel (mixed use is possible);
- The population and required elevator group for normal operation has been determined in accordance with the DTA “Elevator Traffic Handling”. This DTA focuses on high-rise office, residential and hotel towers and offers reference design criteria for population per floor, the use of stairs, peak handling capacity, peak flow direction (incoming, outgoing, inter-floor traffic split), simulation type and parameters, waiting and destination times, nominal travel times and lobby depth;
- There is no panic among evacuees. Panic prevention strategies can be found in (Wit, 2010).

The DTA “Evacuation Using Elevators” has a broader perspective on evacuating high buildings than just the use of elevators. It focuses on combined use of stairs and elevators, and defines the following possible scenarios¹⁾:

0. Only stairs (current Dutch situation, no mandatory solution for wheelchair users and otherwise mobility impaired persons, see figure 1);
1. Only stairs, with fractional evacuation of mobility impaired persons with firefighting elevators;
2. Only elevators (stairs remain available for people reluctant to use elevators);
3. The use of transfer floors (safe havens, refuge areas), for instance every 20 floors, where people flee to by stairs, and are picked up from by elevators in shuttle operation. Additional fractional evacuation of mobility impaired persons with firefighting elevators;
4. Free choice, both stairs and elevators are available for evacuation.

Apart from the elevator evacuation model presented in this paper, an enhanced stair evacuation model has been developed as well (Noordermeer, 2010). It includes stair egress in free- and full-flow conditions and is based on pedestrian models by (Fruin, 1987). It is not set up in the traditional linear way, but with additional delay factors for fatigue, blockage risks and demographic conditions. Also, for scenario 3, an additional elevator model was developed for shuttle operation between refuge and transfer floors. This model was not based on up-peak capacity, but on simplified actual round trip time calculation.

3 THE ELEVATOR EVACUATION MODEL

3.1 The original CTBUH approach

In 2004, the Council on Tall Buildings and Urban Habitat (CTBUH) published “Emergency Evacuation Elevator Systems Guideline”. The CTBUH approach to evacuation time is based on the up-peak performance of the elevators, which can be defined by the peak traffic handling. The volume of traffic to be handled in up-peak is called $HC5_{peak}$, defined as the percentage of the building population to be handled in the busiest 5 minutes of the up-peak.

The theoretical time required to fill a building is defined as:

$$T_{up-peak} = 500 / HC5_{peak} \quad [\text{min}] \quad (1)$$

In the CTBUH approach the evacuation time when using elevators, $T_{evac,e}$, is defined as:

$$T_{evac,e} = T_{up-peak} / 1.6 \quad [\text{min}] \quad (2)$$

The factor 1.6 in eq. (2) illustrates the fact that the transportation capacity of elevators in down-peak evacuation mode is higher than in up-peak traffic. This efficiency boost can be explained by the traffic handling routine: where elevators make multiple stops for disembarking during up-peak traffic, they will generally stop only once per cycle to collect evacuees during downwards evacuation traffic. Additionally, the CTBUH publication defines the following three basic evacuation modes, as illustrated in figure 2:

- Total evacuation - when the total building population is evacuated;
- Staged evacuation - when only a limited number of floors is evacuated;
- Fractional evacuation - when only a limited fraction of the total population per floor is evacuated by elevators (wheelchair users and otherwise mobility impaired persons).

¹⁾ Combining these scenarios in a building zone or in different stacked zones is possible.

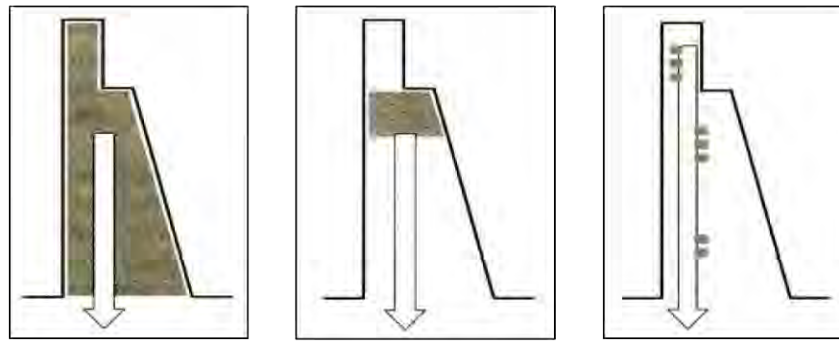


Figure 2. Total evacuation, staged evacuation and fractional evacuation (CTBUH, 2004)

Although the CTBUH approach offers a useful first indication of the possible $T_{\text{evac},e}$ using elevators in high-rise buildings, the equation is only applicable for total evacuation and only relates to up-peak traffic. It is not clear how $T_{\text{evac},e}$ is influenced by fractional and staged evacuation. Furthermore, the CTBUH efficiency factor relates to pure up-peak traffic, possibly making its use for hotel and residential towers, where traffic is mainly bi-directional and down-peak respectively, unreliable.

3.2 Additional factors of influence

In the DTA “Evacuation Using Elevators” the CTBUH approach is scaled to the perspective of the Dutch High-rise Covenant and enhanced for the following influences:

- The optimized traffic handling in evacuation mode, also for bi-directional traffic in hotel towers and down-peak traffic in residential towers: $F_{\text{efficiency}}$
- The fraction of the population per floor to be evacuated: F_{fraction}
- The size of the stage (number of levels) to be evacuated: F_{staged}
- The height of the stage to be evacuated: F_{height}
- The car loading during evacuation: F_{load}
- The number of available elevators for evacuation: $F_{\text{elevators}}$

These influences have been incorporated in the enhanced eq. (3) for calculation of $T_{\text{evac},e}$:

$$T_{\text{evac},e} = T_{\text{up-peak}} \times (F_{\text{fraction}} \times F_{\text{staged}} \times F_{\text{height}}) / (F_{\text{efficiency}} \times F_{\text{load}} \times F_{\text{elevators}}) \quad [\text{min}] \quad (3)$$

To determine the effect of the above mentioned factors, hundreds of elevator simulations have been made using the simulation tool Elevate. First the required elevator configurations for building heights of 70, 100, 150 and 250 meters were established for a range of office, hotel and residential towers, using the DTA “Elevator Traffic Handling” as a reference. Then all these virtual buildings were evacuated using the available elevators while $T_{\text{evac},e}$ was recorded. For various configurations fractional and staged evacuation were investigated as well. Finally, from the results six additional equations for the influence of above mentioned factors were established. These six equations will be discussed in chapters 3.2.1 through 3.2.6. They apply to evacuation scenarios 1, 2 and 4.

3.2.1 F_{fraction}

The influence of the fraction of the population to be evacuated per level is as follows:

$$F_{\text{fraction}} = 0.1 + 0.9 \times (P_{\text{evac}} / P_{\text{peak}}), \quad (4)$$

where P_{evac} stands for the population per floor to be handled in evacuation mode, while P_{peak} stands for the total population per floor handled in the peak period during normal operation. Eq. (4) was derived from figure 3, showing the experimental results for several fractional elevator simulations. The relationship between F_{fraction} and the evacuation fraction ($P_{\text{evac}} / P_{\text{peak}}$) is almost linear, but for small evacuation fractions, F_{fraction} converges to 0.1. This can largely be explained by the fact that for very small fractions, the number of elevator stops during one evacuation cycle becomes dominant (2-8 instead of 1-2 stops). More stops are needed to fill the car, because at every stop only a few people enter. This negatively influences the efficiency of the evacuation routine. Also, because this concerns the fraction of the population not able to evacuate by stairs, there is a relative increase of (dis-)embarking times and car area consumption per person.

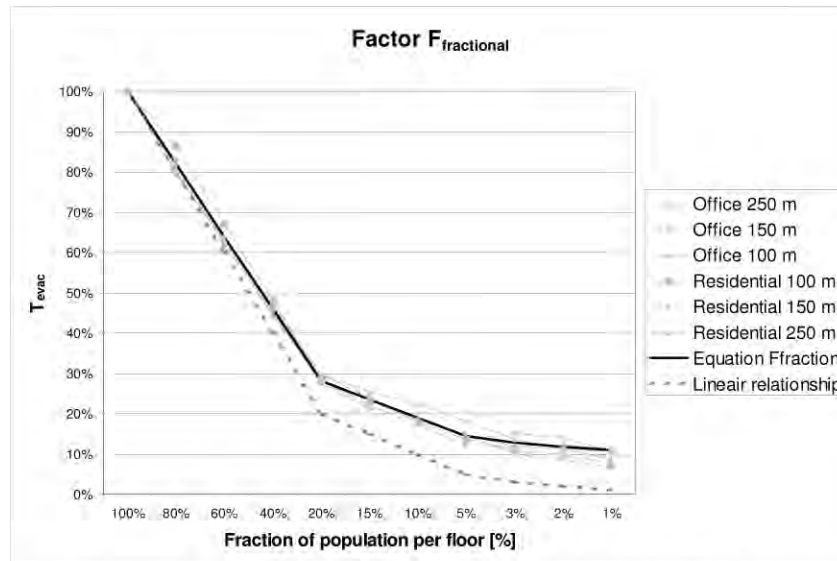


Figure 3: Simulation results (selection) for $F_{fraction}$ analyses²⁾

3.2.2 F_{staged}

The influence of staged evacuation is as follows:

$$F_{staged} = N_{evac} / N_{peak}, \quad (5)$$

where N_{evac} stands for the number of levels to be evacuated, while N_{peak} stands for the number of levels serviced during normal peak operation by the same elevator group. The influence of the height of these evacuated levels is addressed in 3.2.3.

3.2.3 F_{height}

Apart from the number of levels to be evacuated during staged evacuation, the relative position of these levels in relation to all levels to be serviced in normal operation has to be taken into account as well. For instance, it will take less time to evacuate the lowest quarter of a 40 level building, than it takes to evacuate the highest quarter of this building. The effect of this on $T_{evac,e}$ has been researched by various additional evacuation simulations, by varying the serviced floors in normal operation and the fraction and position of the serviced floors in staged evacuation operation. An illustration of the relative influence is given in the left half of figure 4, and an example of the data with which the required equation for this effect has been developed can be found in the right half of this figure.

The influence of the height of the levels to be evacuated in staged operation is as follows:

$$F_{height} = 0.7 + 0.3 \times (H_{high,evac} + H_{low,evac} - H_{low,peak}) / H_{high,peak}, \quad (6)$$

where $H_{high,evac}$ stands for the highest floor level to be evacuated during staged evacuation, while $H_{low,evac}$ stands for the lowest floor level to be evacuated. $H_{high,peak}$ stands for the highest floor level to be serviced in normal operation, while $H_{low,peak}$ stands for the lowest floor level to be serviced during normal operation. If the center of gravity of the evacuation stage lies higher than the center of gravity of the floor levels in normal operation F_{height} becomes larger than 1. Likewise, if the center of gravity of the evacuation stage lies lower than the center of gravity of the floor levels in normal operation F_{height} becomes smaller than 1. The deviation of F_{height} around 1 depends on the relative difference in both centers of gravity and the relative height of the serviced elevator zone in relation to ground level (low-rise zone versus high-rise zone).

²⁾ Since the population density in hotel buildings generally lies between that of office and residential buildings, the hotel graph lines have not been included in this figure.

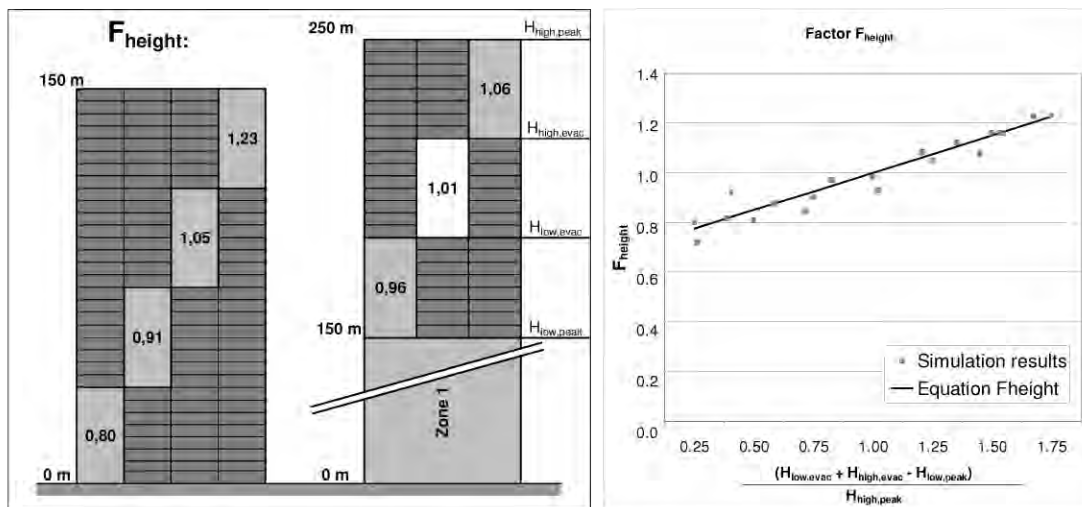


Figure 4: Height influence of the staged evacuation floors

3.2.4 $F_{\text{efficiency}}$

Like the CTBUH, others before have suggested using an efficiency factor to determine the effect of boosted performance in down-peak evacuation operation. This boost originates from the fact that in up-peak traffic destinations are multiple and scattered along the travel height, while in evacuation mode a shuttle-like operation emerges with only 2-3 stops per cycle. (Fortune, 2002) suggests that elevator groups in offices can handle up to 25% of the population per 5 minutes, evacuating a building in 20 minutes or less. (Barney, 2003) suggests that down-peak capacity is approximately 60% higher than up-peak capacity, resulting in 25% evacuation capacity per 5 minutes and thus a 20 minute evacuation time, assuming a 100% car load instead of the usual 80%. (Siikonen, 2002) concludes that during evacuation, traffic handling is 1.5 to 1.8 times more efficient than during up-peak. All statements refer to elevator groups that were designed in up-peak operation.

For the DTA "Evacuation Using Elevators", numerous simulations have been done to determine the efficiency effect for the three considered building functions. From the results, $F_{\text{efficiency}}$ was found to have a range depending on several factors, including travel height and group size. The range and recommended value can be found in table 2. For safety reasons, the recommended $F_{\text{efficiency}}$ in this table is the lower limit of the range.

Table 1: $F_{\text{efficiency}}$ for different building functions

	Office	Hotel	Residential
$F_{\text{efficiency}}$ result range	1.6-1.9	1.9-2.2	2.4-2.8
Recommended $F_{\text{efficiency}}$	1.6	1.9	2.4

$F_{\text{efficiency}}$ turns out to be significantly higher for hotels and residential towers than for office towers. For an explanation please refer to (Wit, 2010).

3.2.5 F_{load}

It is commonly accepted that effective car loads can be higher in evacuation conditions than in normal peak operation. Although 100% car loads are not to be expected, a 10% to 20% increase of the actual car load while evacuating with elevators is realistic. The effect of the increased car load is estimated according to the numbers in table 2.

Table 2: F_{load} for different building functions

	Office	Hotel	Residential
F_{load}	1.1	1.2	1.1
CL_{max} (maximum car load in normal operation)	80%	70%	80%

Please note that these factors are related to the maximum car load that is permitted in the DTA “Elevator Traffic Handling” for normal operation. They also leave additional car space for a safety warden, if present, in office and hotel towers.

3.2.6 $F_{\text{elevators}}$

The effect of the fraction of elevators available for evacuation, in relation to the number of elevators used in normal peak operation, is as follows:

$$F_{\text{elevators}} = E_{\text{evac}} / E_{\text{peak}}, \quad (7)$$

where E_{evac} stands for the number of elevators from the group available for evacuation, while E_{peak} stands for the total number of elevators in the group for handling the peak period during normal operation. This factor makes it possible to make evacuation time calculations for situations where:

- Not all elevators in the group are equipped for evacuation purposes;
- One or more elevators from the group are out of order;
- One or more elevators from the group have been assigned to different stages;
- One or more elevators from other groups have been added to the evacuation routine.

From a Dutch perspective, this is a very relevant factor, due to the fact that the firefighting elevators are usually integrated into the high-rise elevator group. After arrival of the fire department these will no longer be available for evacuation purposes.

3.3 Shuttle operation for transfer floors in evacuation scenario 3

In scenario 3 elevators almost operate as shuttles that only serve a limited number of evacuation floors. The equations to be used are rather different, mainly because there is no scattered call demand in normal operation. Subsequently $F_{\text{efficiency}}$ is not applicable. The following additional set of equations was derived:

$$T_{\text{evac,e,3}} = C_{e,1} \times T_{\text{cycle}} + T_{\text{additional}} \quad [\text{s}] \quad (8)$$

$$C_{e,1} = C_{\text{total}} / E_{\text{evac}} \quad [\text{cycles}] \quad (9)$$

$$C_{\text{total}} = P_{\text{total}} / CL_{\text{evac}} \quad [\text{cycles}] \quad (10)$$

$$CL_{\text{evac}} = (L / 75) \times F_{\text{load}} \times CL_{\text{max}} \quad [\text{persons}] \quad (11)$$

$$T_{\text{cycle}} = 2 \times T_{\text{travel}} + T_{\text{process}} \quad [\text{s}] \quad (12)$$

$$T_{\text{travel}} = (H_{\text{average}} / V + V / A) \quad [\text{s}] \quad (13)$$

$$T_{\text{process}} = 2 \times T_{\text{doors}} + CL_{\text{evac}} \times (T_{\text{in}} + T_{\text{out}}) \quad [\text{s}] \quad (14)$$

$$T_{\text{additional}} = (N_{\text{evac,3}} - 1) \times (V/A + T_{\text{doors}}) \quad [\text{s}] \quad (15)$$

In these equations:

- $N_{\text{evac,3}}$ is the number of evacuation transfer floors in scenario 3 (preferably ≤ 3) and is 1 for a sky lobby shuttle;
- $C_{e,1}$ is the number of cycles required for one elevator (the last one to be finished). $C_{e,1}$ is to be rounded off upwards;
- T_{cycle} stands for the average required time for one evacuation cycle;
- $T_{\text{additional}}$ is the extra time, needed for possible extra local stops during the last cycle of the last elevator, for evacuation the last remaining people per floor;
- C_{total} is the total number of cycles, required for evacuation of P_{total} . C_{total} is to be rounded off upwards;
- P_{total} is the total population to be evacuated;
- CL_{evac} stands for the car load during evacuation. CL_{evac} is to be rounded off downwards;
- L stands for the nominal load of the elevators in [kg];
- CL_{max} is the maximum car load percentage from table 2;
- T_{travel} is the time required to travel between the transfer or sky lobby floor and the building exit floor;
- V is the nominal speed of the elevator in [m/s];

- A is the acceleration of the elevator in $[m/s^2]$;
- $H_{average}$ is the weighted average of the return height of the travel cycle;
- $T_{process}$ is the required process time per cycle for opening + closing doors (T_{doors}), boarding (T_{in}) and debordering (T_{out});
- T_{doors} is assumed to be 10 seconds for evacuation, including a bonus for possible repeated door closing;
- T_{in} is assumed to be 1.5 seconds on average, including a "crushing" bonus;
- T_{out} is assumed to be 1.0 seconds on average.

3.4 Validation

The integrated elevator and stairs evacuation model was validated using elevator simulations for a wide range of possible towers and benchmarked with real evacuation time data. The found reliability interval of the equations presented in this paper turns out to be between -5% and +15% for the combined effect of $F_{efficiency}$, $F_{fraction}$, F_{height} and the shuttle equations. The equations for F_{staged} , F_{load} and $F_{elevators}$ are accurate due to their linear relationship to the evacuation routine.

So, in almost all possible cases the model turns out to be accurate, with evacuation time estimation on the safe side of reality. Few negative results were found (where the model could offer a too positive estimation of the evacuation time) and they only occurred for extremely densely populated towers. In these situations, the traffic handling quality of the present elevators was considered "sober" to begin with, due to rather high waiting times resulting from a minimally required amount of elevators present. Because evacuation time is a safety issue and a matter of life and death, the use of a 10% overall safety factor for these kinds of towers is recommended.

4 RESULTS

Using the elevator and stairs evacuation model, several case towers have been studied. The main goal here was to establish reference values for probable evacuation times and to evaluate the relative performance of the evacuation scenarios in relation to the buildings function and height. In the figures 5 through 7 some experimental results are shown for office, residential and hotel towers. The evacuation time has been calculated for several heights and for the five established evacuation routines.

In all cases, 10-20% of the population was evacuated by elevators when applying fractional evacuation, to reduce stairwell congestion. In the free choice scenario, a constant division of 50%-50% was assumed.

As can be seen in figure 5, congestion in the stairwells becomes dominant in office towers above 150 meters. This can be explained by the high density of the population, in comparison to residential and hotel towers. Therefore, stairs only evacuation and fractional evacuation are only adequate scenarios up to approximately 100 meters. Above 150 meters, the focus should be using elevators only, using refuge areas or offering free choice between stairs and elevators. The free choice scenario offers the lowest possible T_{evac} up to 250 meters, namely below 20 minutes.

Furthermore, the evacuation time using elevators appears to be rather constant over the buildings height, as the number of elevators increases with the number of levels. It is indeed between 20 and 25 minutes for office towers, confirming earlier research by (Siikonen, 2002), (Fortune, 2002) and (Barney, 2003).

As can be seen in figure 6, the congestion risk in stairwells is substantially lower for residential towers than for office towers. On the other hand, the capacity of the elevators is limited, due to a limited peak demand in normal operation. As a result, in residential towers up to 150 meters, stairs only evacuation offers lower evacuation times than elevators only evacuation. When combining both stairs and elevators for fractional evacuation, evacuation times below 20 minutes can be established up to 250 meters high. In residential towers, the focus should be on fractional evacuation, using the elevators for the evacuation of mobility impaired people.

As can be seen in figure 7, evacuation in hotel towers steers a middle course between office and residential towers. On the one hand, population density is not as high as in office towers, reducing stairwell congestion considerably. On the other hand, due to the high peak demand and required customer satisfaction level in normal operation, a high number of elevators will be available for evacuation. As a result, hotel towers offer the lowest possible evacuation time of the 3 considered building types.

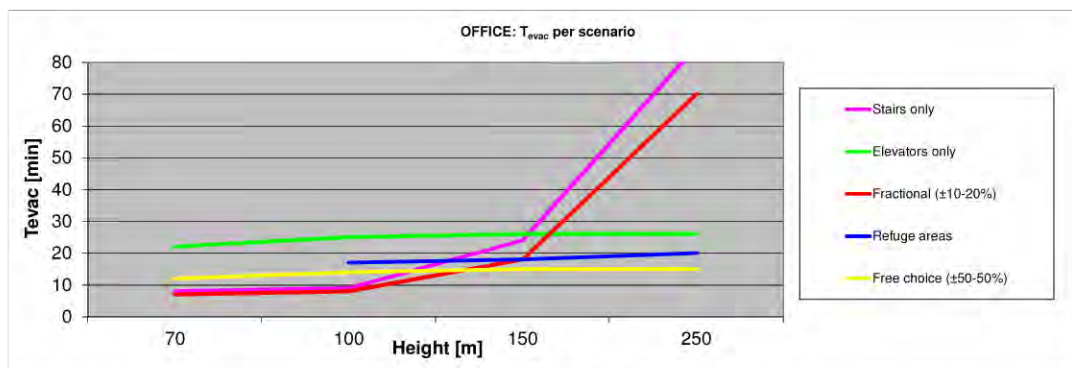


Figure 5: Evacuation times for office towers

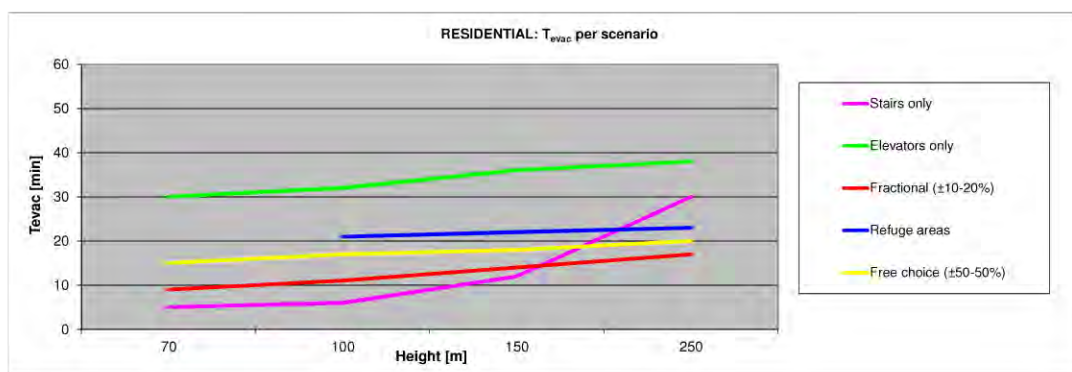


Figure 6: Evacuation times for residential towers

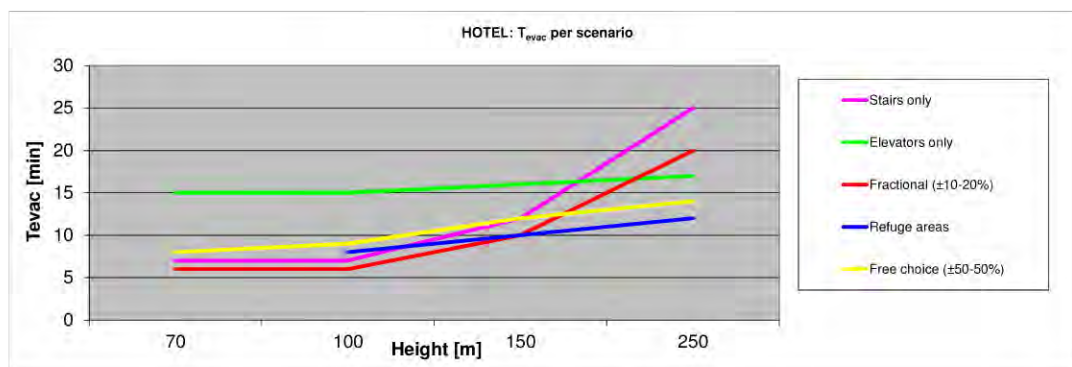


Figure 7: Evacuation times for hotel towers

Although all the evacuation scenarios offer acceptable evacuation times, fractional evacuation should be aimed for up to 150 meters, and refuge area evacuation or free choice evacuation above 150 meters.

One general remark should be made for all of these graphs: when people have to transfer from one elevator group to another in buildings with sky lobbies, successive waiting times can get longer and shuttle transportation becomes dominant. This would generally occur in towers of 250 meters and upwards. Since the $F_{efficiency}$ does not apply to shuttle operation, the shuttles may even prove to be the bottleneck in the evacuation procedure. Depending on the tower's lay-out and function sky lobby shuttle delay can be about 10-20 minutes. The delay is limited in relation to the fact that local evacuation and shuttle evacuation does not take place successively, but simultaneously.

5 CONCLUSIONS

Studies using the combined stair and elevator model from this DTA show that:

- The enhanced elevator model offers the possibility to estimate $T_{\text{evac,e}}$ for fractional and staged evacuation, including factors for improved car load and (reduced) number of available cars, not only for office buildings, but also for hotel and residential buildings;
- Using elevators and stairs for evacuation simultaneously does significantly reduce the total evacuation time;
- The contribution of elevators to a lower combined evacuation time increases as tower height and population density increase;
- The enhanced elevator and stairs evacuation model offers an opportunity to compare the performance of several evacuation strategies for high-rise towers;
- Fractional evacuation is optimal to about 100-150 meters for all the considered building types, for taller buildings refuge floor and free choice evacuation result in a minimal evacuation time;
- When applying fractional evacuation, the fraction should preferably not just consist of wheelchair users, but include every person not (physically or mentally) capable of descending dozens of stairs. A fraction of 10-20% should be anticipated for significant reduction of stair evacuation times. By doing so slow descenders (with higher blockage risk) are evacuated by elevators and free flow in the stairwells is almost guaranteed.

6 RECOMMENDATIONS FOR FUTURE RESEARCH

Current recommendations for further research are:

- Validation for even higher towers and higher populations per floor;
- Expanding use to health care buildings and (crowded) public functions, such as conference centers and restaurants;
- Expanding for double deck elevators and TWIN elevators;
- Organizing a real high-rise evacuation drill with elevators in the Netherlands to further validate the outcome of the model;
- Enhancing the free choice scenario for other fractions of stair users and elevator users, varying over height;
- Translating the DTA text into English for international access.

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