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Appendix 12. Data analysis for the possibility of escape and survivability

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The possibility of escape and survivability have been determined based on:
> Three different groups
> The times for the possibility of escape and survivability for these three groups (for the first floor)
> The percentages of threshold values at 20 minutes for certain situations within the possibility of escape and survivability for these three groups (for the first floor)
> The carbon monoxide concentrations (for the ground floor, second floor and third floor)

The choices made and steps taken for these four aspects are explained below.

A. Three different groups

The effect of the fire conditions on the possibility of escape and survivability differs from person to person. As mentioned in section 1.3.5 of the report, certain sub-populations are more vulnerable to these conditions than others and so a sensitivity factor (sf) is used to represent this vulnerability. Since vulnerability to the conditions differs from person to person, this research uses the sensitivity factor to distinguish between three groups:
> General group, sf = 1
> Vulnerable group, sf = 0.3
> Highly vulnerable group, sf = 0.1

In combination with the threshold values per method in section 1.3.5 of the report, this leads to the threshold values for groups, methods and situations given in table 1. These threshold values are used in order to determine the times for the possibility of escape and survivability.

Table 1 Overview of the threshold values according to SFPE

Fire condition	Method	Impaired			Life-threatening			Fatal		
		Highly vulnerable	Vulnerable	General	Highly vulnerable	Vulnerable	General	Highly vulnerable	Vulnerable	General
Irritant gases	FIC/FLD	0.1	0.3	1.0	0.5	1.5	5	0.1	0.3	1.0
Asphyxiant gases	FED_{IN}	-	-	-	0.1	0.3	1.0	0.2	0.6	2.0
Heat	FED_{heat}	0.1	0.3	1.0	0.8	2.4	8.0	1.2	3.6	12.0
Visibility	FEC_{smoke}	0.1	0.3	1.0	-	-	-	-	-	-

B. Times for the possibility of escape and survivability (first floor)

The times for the possibility of escape and survivability for the three groups have been calculated on the basis of the fire conditions heat, visibility, irritant gases and asphyxiant gases, measured for the individual tests and rooms. The times are based on the measurement data of the tests (see appendix 16). Here, the measurement data of the tests of variant 0 (door open, door to the fire room opened after 5 minutes until at least 20 minutes) and the tests of variant 1 (door closed, door to the fire room open between 5 and 5.5 minutes, and then closed until at least 20 minutes) have been used. The tests of variant 0 (door open) and variant 1 (door closed) serve as the basis for the comparison with the tests where supplementary measures were applied. In addition, the tests of variant 8 (balcony door open and door open, maximum ventilation) were used. These tests were conducted to examine whether an open balcony door had a major influence on the times for the possibility of escape and survivability.

As stated, the measurement data from the tests are the basis for the times calculated for the possibility of escape and survivability. The following checks were done to ensure the reliability of the measurement data:

> The measurement data were examined for any anomalies or other remarkable aspects which might indicate measurement errors. Any remarkable aspects of the measurement data were examined for their influence on the times for the possibility of escape and survivability.
> The visibility distance measured in the corridor was compared with the camera images.

After assessing the reliability of the measurement data, the times for the possibility of escape and survivability were calculated for the three groups. The times were calculated as follows:

> Calculate the development of the different methods per test, room, situation and group.
> Calculate the times when the threshold value was exceeded for each method, and for each test, room, method, situation, and group.
> Determine which method results in the shortest time until threshold values are reached.
> Calculate the average value of the individual times of two measuring points in corridor 1.2 for the two heights at which measurements were conducted.
> The shortest times determine the times for the possibility of escape and survivability for the test in question.
> If one test was conducted for a certain variant, the times measured for this test will automatically be the times for the variant in question.
> If several tests were conducted for one variant, the average value of the times of the individual tests was calculated to establish the average time for one variant. If the threshold value was not exceeded during the first 20 minutes of the test, the time when it was exceeded after 20 minutes, with a maximum of 55 minutes (end of the test), was assumed.

The following choices were made when calculating the times:

> The following measured gases were taken into account:
  – FIC (irritant gases): NO and NO_2
  – FLD (irritant gases): NO and NO_2
  – FED_{in} (toxic gases): CO, CO_2, O_2, NO, NO_2 and NO_x
  – FED_{heat} (heat): Temperature and radiation (if measured at the location in question)

  - FEC_{smoke} (visibility): optical density (only in corridor 1.2)

> FIC (irritant gases) en FEC_{smoke} (visibility): once exceeded, a threshold value will continue to be exceeded, even if the concentration later falls to below the threshold value. For example, the visibility distance or the irritant gas concentration can improve after some time. This was not taken into account in the times.
> FIC (irritant gases): a threshold value of 200 ppm of nitrogen monoxide (NO) was assumed for the impaired escape situation.
> FED_{heat} (heat): an unclothed or lightly clothed person was assumed for the convected heat calculation.
> FEC_{smoke} (visibility): the threshold value of a small room was assumed for the visibility distance (visibility distance of 5 metres).

Analysis of the times

When analysing the times for the possibility of escape and survivability, times rounded to whole minutes were considered in order to account for the uncertainty in the measurements and in the calculation method. When analysing the times, only the first 20 minutes of the test (the escape phase) were considered since the fire service deployment might influence the propagation of smoke and hence the times for the possibility of escape and survivability. Besides the times when the threshold values for impaired escape, a life-threatening situation or a fatal situation were exceeded, the following aspects were also examined:

> Which fire condition(s) caused the threshold values to be exceeded. This may help find possible solutions for improving the times for the possibility of escape and survivability. There are some uncertainties to all methods for calculating the possibility of escape and survivability. If a fatal situation occurs on the basis of two methods, this gives more certainty.
> Whether any smoke was seen on camera images where no carbon monoxide was measured. This was done because gases were only measured at one location in a room. If smoke was also seen in a room, this might indicate that asphyxiant or irritant gases were locally present even though the measurements did not detect them.
> The amount of smoke seen on camera images in corridor 1.1 and corridor 1.3. The visibility distance was not measured in corridors 1.1 and 1.3. The camera images enable a rough estimate to be made as to whether there might be an impaired escape situation. Since this is only a rough estimate, the degree of visible smoke has been described.
> Visibility in corridor 1.2 based on camera images for the moments when the visibility distance in the corridor increased again. This was done because soot deposited on the visibility distance meters may have affected measurements. Of course, the camera images can also be affected by soot on the lens. A cross-check between the camera images and the visibility distance meters was used to analyse visibility in the corridor as well as possible.

C. Percentages of threshold values at 20 minutes (first floor)

In addition to the times when the threshold values for the possibility of escape and survivability were exceeded, the percentages of the threshold values at 20 minutes were also considered for those situations where the threshold value had not been exceeded, since this percentage shows whether certain threshold values might *be on the brink* of being exceeded. This provides clarity as to whether staying in a room for more than 20 minutes

might still lead to an impaired escape, or a life-threatening or fatal situation. The percentages were calculated as follows:

> The variants where a threshold value was not exceeded for a certain group and room were identified. This was based on the average times for the possibility of escape and survivability per variant.
> For those cases where a threshold value was not exceeded, the percentage of a threshold value per group, room and method at 20 minutes was examined for every individual test.
> The highest percentage of the different methods for the individual groups, rooms and tests was determined.
> Where several tests of one variant were conducted, the percentages of the different tests were used to calculate an average percentage for the variant in question.

As stated, the percentage at 20 minutes was assumed for calculating the average percentage per variant. The average time when a threshold value was exceeded was calculated when calculating the times for the possibility of escape and survivability. This sometimes led to a difference between the two calculation methods. In the method described above, there may be cases where the average percentage of a threshold value at 20 minutes exceeded 100%, whereas, based on the average times for the possibility of escape and survivability, the threshold value in question was not exceeded.

D. Comparison between variants

When determining the average times for several tests of one variant, the differences between these tests were examined. This was done in order to assess whether more variables than just the variables tested (the variants) played a role in the times found for the possibility of escape and survivability. As part of the comparison between variants, an examination was made as to whether the difference could be attributed to the variables tested or whether another variable may have had an influence. Where there was a major spread, the underlying measurement data was examined for any differences. Table 2 shows how the different variants were compared and how the spread of different tests of one variant was established.

Table 2 Examination of the comparison for the individual elements

Element	Examination method
Survivability in the fire room	The average times per variant for the threshold values for a life-threatening and a fatal situation being exceeded were compared to the average time of the corresponding variant. The first 20 minutes of the test were examined. The following criteria apply to the determination of the effect: Difference -1 to 1 minute = unchanged Difference > 1 ≤ 3 minutes = slight improvement Difference > 3 minutes = improvement Difference is ≥ -1 ≤ -3 minutes = slight deterioration Difference is > -3 minutes = deterioration A difference should show for both the times for a life-threatening situation and those for a fatal situation. At

	least one of these two situations should show the time difference stated above. Two special aspects apply when attributing the effect: - If all the times of a variant were within the spread of the times of the corresponding variant, a slight improvement / deterioration was considered to be 'unchanged'. This was done because it is possible that small differences were not actually caused by the tested variable (variant / measure) itself. - If a plausible cause (other than the tested variable itself) was found in the spread of the times and the underlying measurement data, this is stated.
Possibility of escape in corridor 1.2	The average time when the threshold value for impaired escape was exceeded was compared to the average time of the corresponding variant. The first 20 minutes of the test were examined. The comparisons concerned the heights of 1.5 metres and 0.3 metre. The effect was determined according to the same criteria as for the 'survivability in the fire room'. As regards the possibility of escape in corridor 1.2, a slight improvement was attributed if the threshold values in corridor 1.2 were first exceeded and then improved again after some time, returning to the values for safe escape.
Survivability in corridor 1.2	The average times per variant for the threshold values for a life-threatening and a fatal situation being exceeded were compared to the average time of the corresponding variant. The first 20 minutes of the test were examined. The comparisons concerned the height of 1.5 metres and 0.3 metre. The effect was determined according to the same criteria as for the 'survivability in the fire room'.
Survivability in other residences on the first floor up to 20 minutes	The average times per variant for the threshold values for a life-threatening and a fatal situation being exceeded were compared to the average time of the corresponding variant. Residences 1.20, 1.24 and 1.25 were compared. The first 20 minutes of the test were examined. The effect was determined according to the same criteria as for the 'survivability in the fire room'.
The percentage of non-exceeded threshold values in the other residences on the first floor at 20 minutes	The average percentages per variant for the threshold value for a life-threatening and a fatal situation being exceeded were compared to the average percentage of the corresponding variant. Residences 1.20, 1.24 and 1.25 were compared. The following criteria apply to the determination of the effect: Difference -20 to 20 % = unchanged Difference > 20 ≤ 40 % = slight improvement Difference > 40 % = improvement Difference ≥ -20 ≤ -40 % = slight deterioration

	Difference > -40 % = deterioration The effect is attributed if the criteria were fulfilled for the percentage of the life-threatening situation or the percentage of the fatal situation. If a fatal situation occurred during the first 20 minutes for one of the two tests, this was taken to be a percentage of 100%.
Survivability on the other floors	The carbon monoxide concentrations measured on the ground floor, the second floor, and the third floor were compared to the corresponding variant. If the concentrations measured were lower, this was considered an improvement. If the concentrations measured were higher, this was considered a deterioration.

Comparison between variant 8 and variant 0

The effect of the open balcony door and the door to the fire room being open on the times for the possibility of escape and survivability was established by comparing the tests of variant 8 (balcony door open and door open, maximum ventilation) with those of the tests of variant 0 (door open).