ISO DIS 8100-32 on Planning and Selection of Passenger Lifts

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Abstract. Work to revise the ISO 4190-6:1984 standard on lift planning and selection of passenger lifts, to be installed in residential buildings [1], started in 2014. This spring (2019), the new ISO DIS 8100-32 [2] was approved for the final ballot. The Draft International Standard (DIS) extends the lift traffic planning, from residential buildings of the current standard ISO 4190-6, to planning and selection of passenger lifts to be installed in office, hotel and residential buildings. In addition, the draft document takes into account the accessibility for persons with impaired disabilities. The draft considers not only the morning up-peak traffic but also traffic mixes for lunch hour and two-way traffic. It can be applied to conventional control with up and down call buttons and destination control systems. The use of the planning methods is demonstrated by examples in the Annexes of the draft document.

1 INTRODUCTION

The current ISO 4190-6 [1] gives a simple guidance for passenger lift selection in residential buildings. Lift selection graphs have been produced using the up-peak traffic formulas. Lift group configuration is selected using the charts for a given number of floors and population. The ISO lift selection standard 4190-6 is from 1984 and needs revision.

In this millennium, discussion started about how to perform lift traffic simulation with stable results [3,4] and how to compare and avoid the misinterpretation of results [5, 6]. ISO TC178 Working Group 6 (WG6) made an initiative to update ISO 4190-6 in the ISO TC178 25th plenary meeting in New York in 2013. A decision was made to revise the current standard, with an extension of the scope to include buildings other than residential buildings.

WG6 established Subgroup 5 (SG5) to conduct the work and named 17 experts in the group. The number of SG5 experts has varied during the years, being currently 14, of which nine were in the original group. The current SG5 members are in alphabetical order of ISO member bodies: Theresa Christy/ASME, Albert Hsu/ASME, Chen Fengwang/ CN, Ming Kai Wang/ CN, Gina Barney/ BSI, Richard Peters/ BSI, Hans Jappsen/ DIN, Jörg Müller/ DIN, Olaf Rieke/ DIN, John Tibbits/ SA, Ami Lustig/ SII, Marja-Liisa Siikonen/ SFS, Janne Sorsa/ SFS and Lukas Finschi/ SNV.

So far, the project has taken about five calendar years. SG5 had its first meeting in Helsinki in spring 2014. Until now, (Summer 2019), there have been totally 51 SG5 meetings, and 11 WG6 meetings where this item has been followed. The first six SG5 meetings were face-to-face, but soon the group discovered that live video-meetings were the best way to conduct the work.

ISO TC178 accepted the revision work as a new working item in 2017. The working draft (WD) was registered as a Committee Draft, ISO CD 8100-32, in September 2018. At the end of 2018 the CD was approved for registration as Draft International Standard (DIS). After the DIS ballot this spring, the ISO DIS 8100-32 was approved for final ballot. The text will be revised and submitted to the ISO Central Secretariat and after that it will go to final ballot for International Standard.

This paper briefly describes the goal of the revision work, the basic principles of the calculation and simulation method, and the effects of the mass and area-based method in choosing the rated load. Finally, a comparison of the selected lift configurations with the current standard ISO 4190-6 and the ISO DIS 8100-32 is demonstrated.

2 GOALS OF THE REVISION WORK

The target of the revision work was to update the current ISO 4190-6 standard to cover offices and hotels, in addition to current residential buildings. SG5 set a goal to develop a simple and quick standard for selecting passenger lifts in different types of buildings that would be in line with the current ISO 4190-6. The revised standard should present state-of-the-art technology and be transparent for users.

For advanced control systems, simulation of more realistic traffic patterns, such as lunch-time traffic, is needed to determine whether the lift(s) are able to handle the traffic in all traffic situations. The state-of-the-art of lift traffic analysis is to simulate passenger traffic in buildings with conventional control, destination control or some other lift system and determine how well the selected lift system serves the defined passenger traffic pattern. Therefore, an additional goal was set to include the traffic simulation as part of the document. The simulator models and validation of the simulator software were considered to be beyond the scope of the document. The simulation method describes only the inputs and the outputs of the simulation, i.e. the traffic patterns that are used as an input for the simulations, and lift performance and passenger service level parameters that are received as an output from the simulation. The calculation and the simulation methods support each other - which can be demonstrated with examples. Simulation gives results in terms of passenger waiting time, as opposed to interval which is provided by the calculation method.

For the lift selection, simple design criteria and their values are defined. To be in line with the current standard, lift selection graphs - to make the initial selection for lift configuration and lift speed - are provided for each building type. The selection graphs can be used as the first approach in defining the lift in the building.

At the beginning of the project, it was thought the task to include consideration of the non-linearity of the car platform area and the rated load was too demanding. In the course of time, however, one more goal for choosing the rated load by mass or area was added in the document.

3 CALCULATION METHOD

The calculation method is based on the up-peak round trip time formula. Up-peak traffic is a situation where people arrive from the main entrance and travel to upper floors. They arrive with a constant arrival rate or following a Poisson arrival process. People enter the nearest car in the lobby until it is filled up to a certain ratio. There is no passenger traffic downwards or between the floors. Lifts are automatically returned to the main entrance when they become vacant, after serving all car calls and all people have exited the cars.

The up-peak round trip time equation was developed in the last century. The development of traffic planning theory was started in the 1920s by the elevator consultant engineer Basset Jones, who derived an equation for the probable number of lift stops in up-peak. In 1923, Mr. Basset Jones [7] derived an equation for the probable number of stops, S, during an elevator up-trip in a building with N floors above the entrance floor and average number of P persons inside the car:

$$S = N\left[1 - \left(1 - \frac{1}{N}\right)^{P}\right] \quad (1)$$

In 1955, Schröder [8] derived the equation for the highest reversal floor, *H:*

$$H = N - \sum_{i=1}^{N-1} \left(\frac{i}{N}\right)^{P} \quad (2)$$

These equations were used by Strakosch [9] and developed further [10]. The most popular form of the up-peak formula, using Eqs. (1) - (2), was introduced in the middle of the 1970s [9]. In the formula t_v is the time to travel between two adjacent floors at rated speed:

$$RTT = 2Ht_v + (S+1)t_s + 2Pt_p \quad (3)$$

In the 8100-32 DIS, the simplest form of the up-peak round trip time equation was selected. Eqs. (1) and (2) assume constant passenger arrival rate and even population distribution on upper floors and Eq. (3) assumes an average floor distance for all floors. More advanced up-peak formulas considering a Poisson arrival process [10] and uneven population distribution [11], uneven floor heights [12], multiple entrances [13] as well as generalisation of the up-peak formulas to involve all traffic situations [14, 15, 16] have been developed and the up-peak formulas have been verified with real traffic [17].

In planning, elevators are expected to transport the whole building population from the lobby to upper floors within about 20-60 minutes, depending on the building or tenant type [18]. Filling times correlate to lift group handling capacity, that show the percentage of the population that the lifts can transport in five minutes. Each building type has its own requirement for lift handling capacity and lift handling capacity should meet the traffic demand of a building. People flow measurements in buildings have revealed that pure up-peak traffic, is often not the worst traffic situation for the lifts during the day, as passenger waiting times during mixed up-peak or lunch time traffic can be much longer. It is difficult to estimate lunch time waiting times accurately with up-peak RTT, since control systems affect the passenger service quality in mixed traffic situations. With traffic simulations, passenger waiting and journey times can be determined in various traffic situations.

4 SIMULATION METHOD

In the simulation method, a simple procedure for how to give inputs and how to print and interpret output results is described. The simulator software and control software are the propriety of the developer companies and are not within the scope of this document. A validation method for the simulation software, however, would be useful in the future [17].

In lift traffic simulation, various traffic patterns can be used for different types of buildings. Some of them are based on measurements, and others describe the traffic situations on a more theoretical basis [19, 20, 21, 22]. According to the measurement results in office building lift lobbies, passengers arrive randomly in office buildings [10]. That is why, in simulation, the passenger arrivals should follow a Poisson distribution. In the ISO simulation method, the simplest possible passenger traffic patterns were defined, i.e. patterns where the passenger arrival rate is constant. For different traffic patterns, the mixes of passengers entering the building, exiting the building or travelling between floors are described. Each building type has its own traffic mixes. The traffic mixes of the constant traffic patterns follow the typical daily traffic profiles, such as morning up-peak and lunch-time traffic in offices. Each defined traffic mix is simulated for several passenger arrival rates.

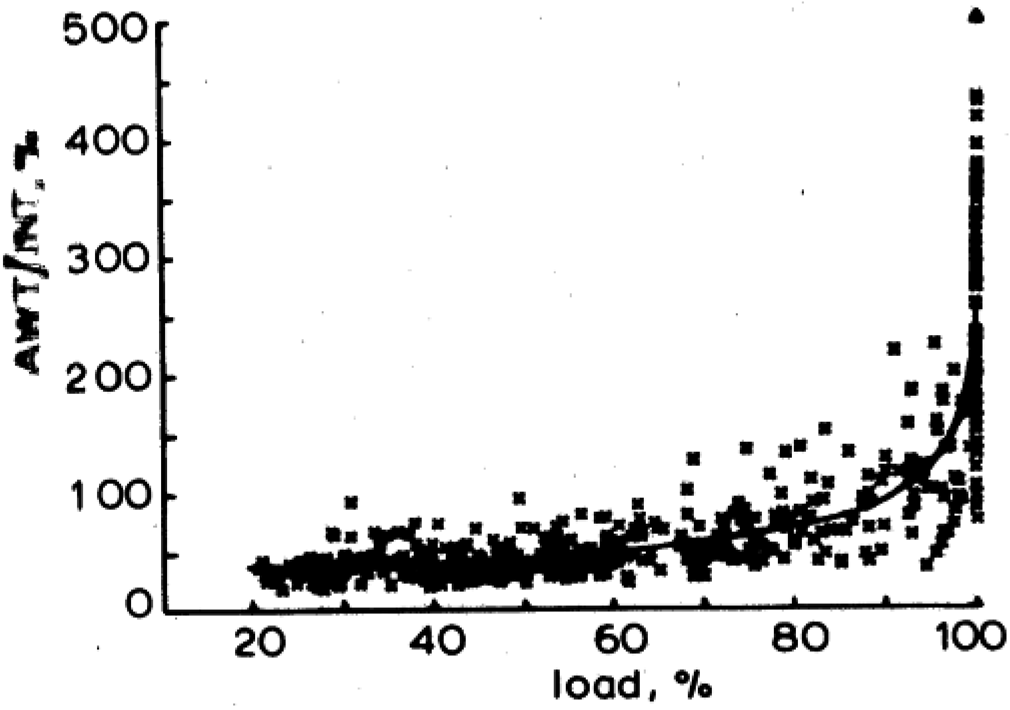

Figure 1: Up-peak waiting time scaled to interval as a function of car loading with collective control system [11]

In the studies of the 1970s and even earlier, it was shown that in up-peak, passenger waiting times start to increase when the traffic demand increases and cars are filled, e.g. close to 80%, of the rated load (see Fig. 1). The rated load of a lift is the load for which the lift has been built and designed to operate. Rated capacity is the maximum number of passengers a lift can transport without being in conflict due to safety norms. It is calculated from the rated load by dividing it by the average mass of a person. The observed measurements show that cars are filled normally to 75-80% of the rated capacity [9]. To consider the comfort of the passengers inside cars, in simulations the maximum number of passengers allowed to enter the car can be set smaller, e.g. 80 % of the rated load.

Waiting times increase rapidly, especially in up-peak, while in other traffic mixes the increase can be slower. In the ISO simulation method, the first simulation is made for arrival rate at the required handling capacity, e.g. 12 % of the building population in five minutes [20, 21]. A series of three simulations is performed with increasing arrival rates, e.g. 12%, 13% and 14% of the population in five minutes. The simulation time for each arrival rate should be long enough, preferably two hours, which ensures stable output results in most cases. For statistical reasons, the first 15 minutes transient from the beginning of the simulation and the last 5 minutes from the end of the simulation are removed [2, 3, 4]. Thus, from a two-hour simulation, the results are analysed for 100 minutes. If, for instance, simulation time was half an hour, the simulation results are analysed for only 10 minutes which is rather a short time for statistical analysis. In this case, to achieve stable results, the simulation should be repeated, e.g. 10 times with slightly different random passenger arrivals.

Average passenger waiting times are calculated for each arrival rate and they are compared to given criteria, e.g. 30 s in office buildings. If the waiting times meet the criteria at all points, the lift configuration can be selected, but it may have excess handling capacity. On the other hand, if none of the simulated average waiting times meet the criteria, the lift configuration can be rejected. If the average waiting time meets the criteria at the arrival rate of required handling capacity and slightly exceeds the given criteria with higher arrival rates, then the lift system meets the requirements of this standard.

5 SELECTION OF RATED LOAD

The lift traffic calculations determine how many passengers a lift or lift group should transport within a certain time, i.e. lift handling capacity. The most important lift characteristics that affect the lift handling capacity are the selected number of lifts, the rated passenger capacity and the speed of the lifts. According to Fig. 1, waiting times start to saturate at an average of 80 % of the rated load. With traffic calculations, the average number of passengers inside a lift is determined, and the rated load is calculated by dividing it by 0.8.

For safety reasons, the car platform area does not increase linearly with the rated load and the rated passenger capacity. The area per person gets smaller with higher loads, which causes a problem in passenger capacity per area. The lift traffic analysis can consider the accommodation of passengers in cars when choosing the rated load. A touch zone of passengers according to Fruin [23] is 0,28 m^2. In crowded cars even densities such as 0,14 m^2 have been observed [9]. The required passenger space depends on the culture and even the gender [24] of the people.

In the selection charts and examples of ISO DIS 8100-32, the average mass of 75 kg [25] and area of 0.21 m^2 per person [23] were chosen. For the passenger mass and area, local measures of each country and area are encouraged to be used. Table 1 shows how the rated load is chosen from the calculated average car load when using the mass-based or area and mass-based selection method.

Table 1: Selection of rated load based on the average number of persons inside a car

Average number of passengers in the car at departure from the main entrance floor	6 persons	8 persons	10 persons	13 persons	16 persons
Area and mass-based selection	630 kg	1000 kg	1275 kg	1600 kg	2000 kg
Mass-based selection	630 kg	800 kg	1000 kg	1275 kg	1600 kg

Example selection of the rated load:

Let's assume that the calculation model has given the result that lifts should be able to transport an average number of eight persons inside a car.

a) Mass-based selection

Assuming a weight of 75 *kg* per person, the lifts should be able transport 8*75 *kg*= 600 *kg* with 80*%* filling ratio. The rated load should be greater than 600/0.8= 750 *kg*. According to ISO DIS 8100-30: 2017 [26], the nearest rated load exceeding 750 *kg* is 800 *kg*, which would be the selected rated load.

b) Area and mass-based selection

Assuming 0.21 m^2 per person, the required area with 80*%* filling ratio 8*0.21 m^2 = 1.68 m^2. For 100*%*, platform area should be 1.68/0.8 = 2.1 m^2. According to ISO 8100-1:2018 [27] the nearest rated load with maximum platform area greater than 2.1 m^2 is 1000 *kg*.

6 FIRST APPROACH FROM SELECTION GRAPHS

In ISO 4190-6 the building may have two entrance floors, the main entrance floor and a parking floor. The floor height is 2.8±0.2 m and the building can have up to 20 floors and the population up to 800 persons. The lift group can include one, two or three lifts with speed up to 2.5 m/s and load up to 1000 kg. The selection charts are formed using the up-peak formula. The criterion for the lift handling capacity is 7.5 % of the population in five minutes, and separate selection graphs are provided for 60s, 80 s or 100 s intervals.

In ISO DIS 8100-32, similar selection graphs as in ISO 4190-6 standard were depicted for the three building types. The graphs are based on the up-peak formula, Eq. (3). The method for how the graphs are produced has been introduced and discussed in previous symposiums on lift and escalator technologies [28, 29]. The selection graphs cover up to 40 floors and a 1200-person population. Lift speeds vary form 1.0 m/s to 3.5 m/s and loads from 630 kg to 1800 kg. For accessibility reasons smaller cars are not included. The floor-to-floor distance varies from 3.0 to 4.0 m depending on the building type. Simple design criteria for the required handling capacity and the interval are given in the document for different types of buildings.

The requirements of ISO 4190-6 and ISO DIS 8100-32 differ slightly. In residential buildings the handling capacity requirement is 7.5 % in ISO 4190-6 and 6 % in the ISO DIS 8100-32. The current standard provides selection graphs for 60 s, 80 s and 100 s intervals, called selection Programmes 60, 80 and 100. In the new DIS, the interval criteria is 60 s. The passenger transfer time in the existing residential graphs was assumed to be 1.75 s, while in the new draft it is 1.0 – 1.2 s depending on the door width. For narrow doors the transfer time is longer than for wider doors.

Table 2: Comparison of lift arrangements in a residential building without parking level [1, 2, 29]

Population / number of floors	**Number of lifts and rated load**			
	ISO 4190-6: 1984			**ISO DIS 8100-32: 2019**
	Programme 100	**Programme 80**	**Programme 60**	
100 / 5	1 x 630 kg	1 x 630 kg	1 x 630 kg	1 x 630 kg *
300 /10	1 x 400 kg + 1 x 1000 kg	1 x 400 kg + 1 x 1000 kg	1 x 400 kg + 1 x 1000 kg	2 x 630 kg*
500 / 15	2 x 1000 kg	2 x 400 kg + 1 x 1000 kg	2 x 630 kg + 1 x 1000 kg	3 x 630 kg*
700/ 20	1 x 630 kg + 2 x 1000 kg	1 x 630 kg + 2 x 1000 kg	-	3 x 800 – 1000 kg*

The lift arrangements according to the selection graphs of the current 4190-6 standard and the new DIS are compared for residential buildings with one entrance floor. Table 2 shows the lift configurations suggested by Programme 100, 80 and 60 of the current ISO 4190-6, and by Figure C.1 of the new ISO DIS 8100-32 [28]. Some low-rise buildings were selected as test examples. According to the table, the number of cars in Programme 60 and Figure C.1 are the same. For a 500-person population and 15 floors, however, Programme 100 suggests one car less than in the other alternatives of the table, since the interval requirement is longer. For accessibility reasons, ISO DIS 8100-32 does not have a car smaller than 630 kg, otherwise the suggested loads are about the same. The graphs in the new DIS show only symmetrical lift groups, but one car in a group is recommended to be at least 1000 kg, to accommodate accessibility requirements and to be able to transport furniture, prams etc.

Table 3: Comparison of lift speeds in a residential building without parking level [1, 2, 29]

Population / number of floors	**Rated speed (m/s)**			
	ISO 4190-6: 1984			**ISO DIS 8100-32: 2019**
	Programme 100	**Programme 80**	**Programme 60**	
100 / 5	0.63	0.63	0.63	1.0
300 /10	1.0	1.0	1.6	1.0
500 / 15	1.6	1.6	2.5	1.6
700/ 20	2.5	2.5		2.0

According to Table 3, the lift speeds of 4190-6 are partly lower and higher than they are in the new DIS. In the new DIS, the speed range starts from 1.0 m/s, and has an additional speed class for 2.0 m/s which makes a difference in the recommended speeds. As a summary, considering the recommended lift groups of ISO 4190-6 Programmes and ISO DIS 8100-32, one can say that they are not exactly the same, but they are in line with each other, considering that they have slightly different handling capacity criteria and constraints in car loads.

7 CONCLUSIONS

In this paper, the main contents of the new ISO DIS 8100-32 are described. SG5 provided demanding goals to the document and after five years of intensive work, found a consensus. The new draft international standard covers passenger lift planning for three types of buildings: offices, hotels and residential buildings. It presents the state-of-the-art technology by covering all types of group control systems and traffic patterns, including a theoretical up-peak traffic calculation and traffic simulation method for other types of traffic patterns. The tables and graphs of the new draft document reflect current lift safety standards and accessibility for persons with disabilities. The final goal of choosing the rated load was solved after thorough discussions. The SG5 arrived at a solution where the rated load can be selected either according to passenger mass, or area and mass. The new DIS is in line with the current standard by providing similar graphs for quick lift selection as in ISO 4190-6, but extending the graphs to cover the three building types.

The subject has inspired the experts of SG5 for long-lasting debates on various issues. Many articles have been published on these subjects during the work, some of which are mentioned in the references of this article: a few of the issues were briefly touched upon in the paper concerning the ISO 4190-6 revision from 2016 [30].

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BIOGRAPHICAL DETAILS

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