INTERNATIONAL STANDARD

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Lifts (elevators), escalators and moving walks — Risk assessment and reduction methodology

Ascenseurs, escaliers mécaniques et trottoirs roulants — Méthodologie de l'appréciation et de la réduction du risque

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 14798 was prepared by Technical Committee ISO/TC 178, *Lifts, escalators and moving walks*.

This first edition of ISO 14798 cancels and replaces ISO/TS 14798:2006, which has been technically revised.

Introduction

The objective of this International Standard is to describe principles and set procedures for a consistent and systematic risk assessment methodology relevant to lifts (elevators), escalators, moving walks ("lifts", for short). The risk analysis and assessment principles and process described in this International Standard may, however, be used for assessment of risk relevant to equipment other than lifts.

This risk assessment methodology is a tool used to identify risk of harm resulting from various hazards, hazardous situations and harmful events. Knowledge and experience of the design, use, installation, maintenance, incidents, accidents and related harm are brought together in order to assess the risk during all phases of the life of lifts[1)] (elevators), escalators and moving walks (hereafter referred to as "lifts"), from design and construction up to decommissioning. The users of the methodology do not make medical judgements but, rather, evaluate events that can possibly lead to levels of harm defined in this International Standard. By itself, this International Standard does not provide a presumption of conformity to any safety requirements for lifts, including those noted in Clause 1.

NOTE Risk assessment is not an exact science, as there is a certain degree of subjectivity in the process.

It is recommended that this International Standard be incorporated into training courses and manuals so as to provide basic instructions on safety aspects to those involved in

a) assessing designs, operations, testing and use of lift equipment, and

b) writing of specifications or standards incorporating safety requirements for lifts.

This International Standard describes a qualitative methodology for risk assessment that relies very much on the judgement and deliberations of the members of the risk assessment team who carry out the assessment. To ensure the most realistic and consistent assessment, it is essential that the methodology be followed faithfully. Aids such as numeric methods of assessment that follow the format described in this International Standard are not precluded from use. It should, however, be recognized that numeric aids to qualitative methods may still retain some of the subjectivity inherent in the qualitative process.

Clause 3 describes the concepts of safety and risk assessment. Clause 4 describes the procedure of risk analysis, including risk estimation. The procedure for risk evaluation is set out in Clause 5 and assessment in Clause 6. Clause 7 deals with protective measures. Clause 8 specifies relevant documentation.

1) Hereafter in this International Standard, the term "lift" is used instead of the term "elevator". In addition, the term "lift" is also used instead of the terms "lifts, escalators and moving walks".

Lifts (elevators), escalators and moving walks — Risk assessment and reduction methodology

1 Scope

This International Standard establishes general principles and specific procedures for assessing risk.

The purpose of this International Standard is to provide a process for making decisions relevant to the safety of lifts during the

a) design, construction, installation and servicing of lifts, lift components and systems,

b) development of generic procedures for the use, operation, testing, compliance verification and servicing of lifts, and

c) development of technical specifications and standards affecting the safety of lifts.

While examples in this International Standard refer primarily to risks of harm to persons, the risk assessment procedure set out in this International Standard can be equally effective for assessing other types of risk relevant to lifts, such as the risk of damage to property and environment.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.1
cause
circumstance, condition, event or action that in a hazardous situation contributes to the production of an effect

2.2
effect
result of a cause in the presence of a hazardous situation

2.3
harm
physical injury or damage to the health of people, or damage to property or the environment

[ISO/IEC Guide 51:1999, 3.3]

2.4
harmful event
occurrence in which a hazardous situation results in harm

[ISO/IEC Guide 51:1999, 3.4]

NOTE In this International Standard, the term "harmful event" is interpreted as a combination of cause and effect.

2.5
hazard
potential source of harm

NOTE The term “hazard” can be qualified in order to define its origin or the nature of the expected harm (e.g. electric shock hazard, crushing hazard, cutting hazard, toxic hazard, fire hazard, drowning hazard).

[ISO/IEC Guide 51:1999, 3.5]

2.6
hazardous situation
circumstance in which people, property or the environment are exposed to one or more hazards

[ISO/IEC Guide 51:1999, 3.6]

2.7
life cycle
period of usage of a component or a lift system

2.8
protective measure
means used to reduce risk

NOTE Protective measures include risk reduction by inherently safe design, protective devices, personal protective equipment, information for use and installation and training

[ISO/IEC Guide 51:1999, 3.8]

2.9
residual risk
risk remaining after protective measures have been taken

[ISO/IEC Guide 51:1999, 3.9]

2.10
risk
combination of the probability of occurrence of harm and the severity of that harm

[ISO/IEC Guide 51:1999, 3.2]

2.11
risk analysis
systematic use of available information to identify hazards and to estimate the risk

[ISO/IEC Guide 51:1999, 3.10]

2.12
risk assessment
overall process comprising a risk analysis and a risk evaluation

[ISO/IEC Guide 51:1999, 3.12]

2.13
risk evaluation
consideration of the risk analysis results to determine if the risk reduction is required

2.14
scenario
sequence of a hazardous situation, cause and effect

2.15
severity
level of potential harm

3 General principles

3.1 Concept of safety

Safety, within this International Standard, is considered as freedom from unacceptable risk. There can be no absolute safety. Some risks, defined in this International Standard as residual risk, can remain. Therefore, a product or process (e.g. operation, use, inspection, testing, or servicing) can be only relatively safe. Safety is achieved by sufficient mitigation or reduction of the risk.

Safety is achieved by the search for an optimal balance between the ideal of absolute safety, the demand to be met by a product or process, and factors such as benefit to the user, suitability for purpose, cost effectiveness and conventions of the society concerned. Consequently, there is a need to review continually the established safety levels, in particular when experience necessitates review of the pre-set safety levels and when developments, both in technology and knowledge, can lead to feasible improvements to attain sufficient mitigation of the risk compatible with the use of a product, process, or service.

3.2 Concept of risk assessment

3.2.1 Safety is achieved by the iterative process of risk assessment (risk analysis and risk evaluation) and risk reduction (see Figure 1).

3.2.2 Risk assessment is a series of logical steps that enables, in a systematic way, the examination of hazards associated with lifts. Risk assessment is followed, whenever necessary, by the risk reduction process, as described in Clause 7. When this process is repeated, it gives the iterative process for eliminating hazards as far as possible and for implementing protective measures.

3.2.3 Risk assessment includes:

a) risk analysis

   1) determination of the subject of analysis (see 4.3),

   2) identification of scenarios: hazardous situations, causes and effects (see 4.4), and

   3) risk estimation (see 4.5);

b) risk evaluation (see Clause 5).

3.2.4 Risk analysis provides the information required for the risk evaluation, which in turn allows judgements to be made on the level of safety of the lift and lift component, and any relevant process (e.g. operation, use, inspection, testing, or servicing).

3.2.5 Risk assessment relies on judgemental decisions. These decisions should be supported by qualitative methods complemented, as far as possible, by quantitative methods. Quantitative methods are particularly appropriate when the foreseeable severity and extent of harm are high. Qualitative methods are useful to assess alternative safety measures and to determine which one gives better protection.

NOTE The application of quantitative methods is restricted by the amount of useful data that is available, and in many applications, only a qualitative risk assessment is possible.

3.2.6 The risk assessment shall be conducted so that it is possible to note down the procedure that has been followed and the results that have been achieved (see Clause 8).

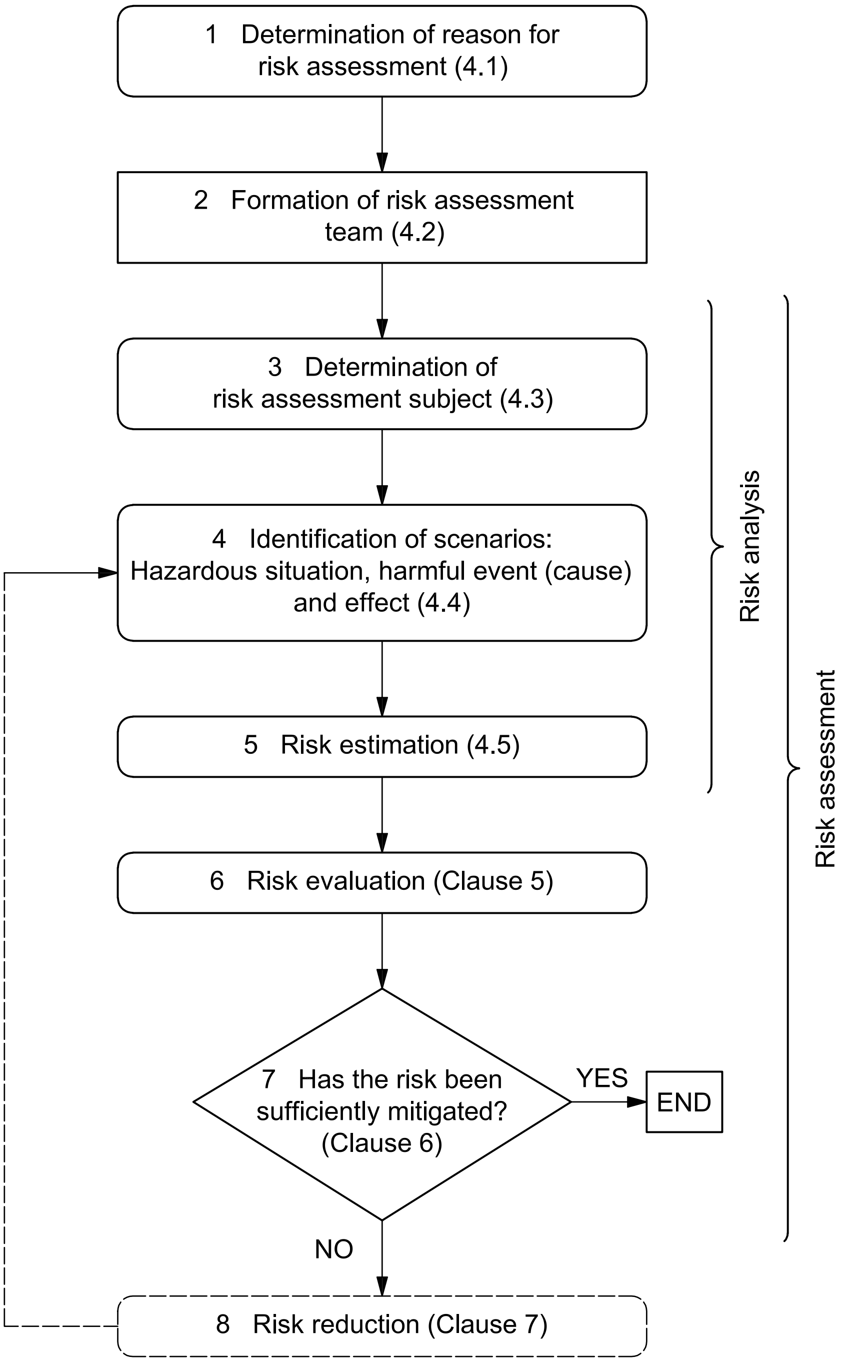


Figure 1 — Iterative process of risk assessment and risk reduction

4 Risk analysis procedure

4.1 Step 1 — Determination of the reason for conducting a risk assessment

Before a risk assessment process can start, the reason for the assessment should be determined. It can be, but is not limited to, the following:

a) verification that the risks are eliminated or sufficiently mitigated in relation to

   1) design for, or installation of, a lift or a component, or a subsystem thereof,

   2) the operation and use of a lift, or

   3) procedures for testing, inspection, servicing, or performing any other work with intent to maintain the lift or a lift component in its intended operating conditions;

   NOTE This especially applies to lifts and their components for which no recognized relevant safety standards are available.

b) development of standards and regulations that stipulate requirements related to lift safety.

4.2 Step 2 — Formation of a risk assessment team

4.2.1 General

Considering the variety in design, process and technology relevant to lifts, the diversity in the interests and working experience of lift experts, and in order to minimize any bias, a team approach for this risk assessment process is preferable.

NOTE Risk assessment carried out by an individual might not be as comprehensive as that carried out by a team.

4.2.2 Team members

Selection of the members of the risk assessment team, including the team moderator, is of paramount importance to the success of this risk assessment process.

The team should be comprised of individuals with varied interests and having experience in all fields that can be affected by the product or process being assessed.

EXAMPLE When assessing the design of a lift with a view to the safety of mechanics who will service the lift, the team can include persons with related work experience in construction, installation, testing, inspection and servicing, in addition to safety experts and experts in the design of various lift systems and subsystems.

Experts with specialized knowledge may be engaged in a consulting role for all or appropriate portions of the risk assessment process. Such participation can significantly enhance the quality of the results.

4.2.3 Team moderator

The team moderator should:

a) have an overall understanding of the product or process being assessed;

b) understand the risk assessment process;

c) be able to assume an impartial view free of any bias;

d) have “facilitating” abilities;

e) act as a facilitator rather than participant in the debates of the team, and

f) be able to facilitate arbitration when no team consensus can be reached.

NOTE For further information on the role and responsibilities of the moderator, refer to Annex E.

4.3 Step 3 — Determination of the subject of risk assessment and related factors

4.3.1 Determination of the subject of the assessment

Once the reason for a risk assessment process is determined in accordance with 4.1, the subject of the assessment shall be determined as precisely as possible. Without limiting generalities, the subject may include one or more of the following:

a) complete lift system

  1) for a specific load, speed, travel, or range thereof,

  2) for any location type, e.g. indoor or exposed to weather, in a public building or private residence, or in a factory or school,

  3) for a specified or unspecified life cycle (see 4.3.2.2),

  4) powered by any drive type (e.g. electric or hydraulic),

  5) in a building that is accessible to the general public or that has strictly controlled use and access thereto, and

  6) for the transportation of persons from the general public, a defined category of persons, goods only, or a combination thereof;

b) component or subsystem of a lift in a), such as

  1) enclosure of lift car, lift well, machine room or machinery space,

  2) drive system or braking system, during normal operation or in case of emergency;

  3) entrances to lift car and lift well (hoistway), machine room or well pit area,

  4) operation control or motion control, incorporating diversified or specific technologies, and

  5) locking devices;

c) persons in relation to a lift in a), such as those who

  1) use the lift for transportation,

  2) are in, or could gain access to, the area where any part of the lift is located or operated,

  3) perform any work on, or in the vicinity of, a lift, such as installing, testing, inspection, servicing, repairing, altering, rescuing, or cleaning (e.g. cleaning pit, car or well enclosures),

  4) have certain physical disabilities, and

  5) perform specific functions, e.g. fire fighting or transportation of hospital patients;

d) processes related to a lift or its components, such as

  1) installation,

  2) service,

  3) repair,

  4) cleaning,

  5) testing,

  6) modernization,

  7) replacement, and

  8) rescue.

4.3.2 Determination of any additional factors and data to be considered

4.3.2.1 General

In addition to the reason (see 4.1) and the subject (see 4.3.1) for the risk assessment, any additional factors that can modify or clarify the subject shall be determined, and any experience with similar products should be taken into consideration in the course of the assessment.

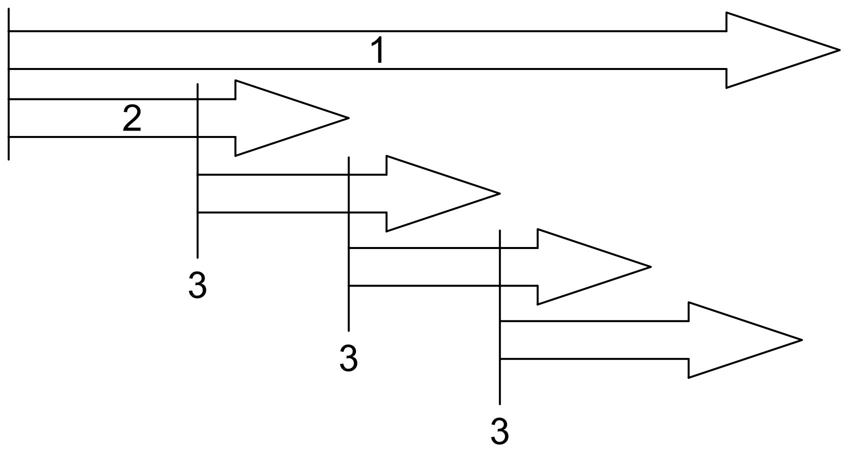
4.3.2.2 Life cycle of the subject being assessed

4.3.2.2.1 The intended life cycle is an important factor in determining the probability that a given event will occur. It does not, however, always come into play. If a standard is being written to address intrinsic safety, the life cycle need not be taken into account.

EXAMPLE A safe gap can be defined by "a dimension not exceeding *x*". This requirement is not related to time. Exceeding "*x*" is deemed to be unsafe.

4.3.2.2.2 Life cycle does have a role when considering the probability that a particular event will occur due to a component failure. In this situation, the life cycle of the system incorporating the component shall be considered. If, for example the system is to perform its function for 8 years, then the life of components shall at least match this to avoid a high probability of failure and, therefore, the occurrence of a given event. If, however, the component, through preventive maintenance, is replaced before failure occurs, the probability of the occurrence of a given event is low.

EXAMPLE 1 If a component expected to perform its safety function no longer than 8 years is incorporated in a lift system that is expected to operate safely during a 20-year interval, the lift will do so only if the component is replaced with a new one in intervals of less than 8 years, as shown in Figure 2.



Key

1 time of system life cycle, 20 years

2 component life cycle, 8 years

3 time of replacement (prior to expected end of component life cycle end)

Figure 2 — Replacement of components with a component life cycle shorter than the system life cycle

EXAMPLE 2 If a component critical for lift safety could fail once, twice or thrice during the life cycle of a lift system, the probability of the failure of the component, as well as the probability of an unsafe condition occurring on the lift system, would be estimated as "C — occasional" when estimating the risk in accordance with 4.5.4 and Table C.2 of Annex C. If, however, there is a programme in place to regularly replace the component before the end of its lifetime, the probability of an unsafe condition occurring in the lift system would be estimated as "D — remote" or "E — improbable", depending on the reliability of the component, as well as the reliability of the replacement programme.

4.3.2.3 Information and data

4.3.2.3.1 Any available information and data that could assist in the qualitative and quantitative analysis should be taken into account. This includes accident and incident history, and causes and effects, which are relevant to the subject of the assessment or to similar products or procedures.

4.3.2.3.2 The absence of an accident history, a small number of accidents, or the low severity of the effects of the accidents should not lead to an automatic presumption of low risk.

4.3.2.3.3 Quantitative data can be used to supplement the data, based on the consensus of expert opinion derived from experience, as described in this International Standard.

4.4 Step 4 — Identification of scenarios: hazardous situations, causes and effects

NOTE 1 In addition to the risk scenarios given in this subclause, Annex B and Annex F, further examples are provided in ISO/TS 22559-1.

NOTE 2 Examples of hazards in Annex B are related to lifts. More general and comprehensive examples of hazards, hazardous situations and harmful events related to machinery in general, are provided in ISO 14121-1.

4.4.1 Hazard identification

4.4.1.1 The focal point of a scenario is the identification of hazards that could be associated with the subject being assessed. Table B.1 lists typical hazards that could be associated with lifts, including details and examples of the hazards. The list can be used as a starting point when formulating a scenario.

EXAMPLE The risk assessment team can start by asking whether there is any situation in which people can be exposed to any type of hazard, for instance mechanical, electrical, fire or chemical.

4.4.1.2 A hazard may be inherent in the functionality of the lift system.

EXAMPLE A lift car and counterweight, when moving adjacent to an open floor or stairway used by people, is an inherent hazard to people. A counterweight moving adjacent to the car inside the lift well is also an inherent hazard to the mechanic working from the top of the car. Both hazards and related situations are covered in Table B.1, item B.1.1 b), and Table B.2, item B.2.1 b).

4.4.1.3 In many cases, a hazard becomes obvious only after a scenario is formulated. Hazards that are not inherent to the functionality of the lift system include the following:

a) hazards associated with the failure of the lift system, a component or a part of a lift or the malfunction of a safety-related system or component (see Table B.3, items B.3.1 and B.3.2);

b) hazards associated with outside influences such as the environment, temperature, fire, climatic conditions, lightning, rain, wind, snow, earthquakes, electromagnetic phenomena (EMC), the condition of the building and its use (see Table B.3, items B.3.4 to B.3.6);

c) hazards associated with inappropriate procedures for the operation, use, service or cleaning of a lift or parts thereof, or other functions performed on a lift or parts thereof; hazards associated with the misuse of the system or process, or related to the disregard of ergonomic principles affecting safety (see Table B.3, item B.3.7).

4.4.2 Formulation of a scenario

4.4.2.1 Scenario

The formulation of a scenario includes the identification of a hazard and the formulation of a hazardous situation, and its cause and effect. It is important to identify and record the hazard(s) before the formulation of the scenario proceeds. It is critical for a scenario to be formulated in the sequence of occurrence of each part of the scenario.

4.4.2.2 Hazardous situations

All situations or other circumstances in which people (or property or environment) can be exposed to one or more hazards should be identified. This applies to all hazardous situations associated with the subject being assessed, throughout the life cycle of the subject (see 4.3). Table B.2 contains examples of hazardous situations in which people can be exposed to the specific types of hazards listed in Table B.1. Table B.2 can help the team (see 4.2) when formulating hazardous situations.

4.4.2.3 Causes

All events that could occur in a hazardous situation and that can create the possibility for people to be exposed to a hazard should be identified. Table B.3 gives examples of causes that can create a possibility of exposure to specific types of hazard.

4.4.2.4 Effects

4.4.2.4.1 The effects that can result from a cause within a hazardous situation shall be identified. Harm may be part of such effects.

4.4.2.4.2 Table B.4 gives the main features of examples of possible effects. For the purposes of risk assessment, in certain cases a more explicit description of a possible effect might be needed in addition to the descriptive format given in Table B.4.

EXAMPLE In the case of an effect of a person slipping and falling on the floor because it is slippery, the description of the effect as "slipping and falling on the floor" might be sufficient for the estimation of the level of severity of the effect, including harm. However, in the case of an effect involving "falling from a height", a more detailed description, such as the height from which the fall occurs, might be needed for the purpose of estimation of the level of severity of the effect, including the harm as the part of the effect.

4.4.2.4.3 When it comes to the description of effects in terms of harm, the team may decide to expand the description of the effect by specifying the nature of possible harm using examples in Table B.5, before proceeding to the estimation of the level of severity of harm (see 4.5.3.1).

NOTE Example 1 of Annex F illustrates two approaches to the description of effect and harm as part of the effect, for the purpose of estimation of the degree of severity.

4.4.3 Recording of scenario elements

Annex F gives examples of identifying and recording the subject of the risk analysis, hazards and scenarios.

It is not always necessary to list all the hazards before formulating relevant hazardous situations and harmful events because, in most cases, the description of the hazardous situation and its causes and effects states the type of hazard being considered. It is, however, important that all members of the risk assessment team (see 4.2) agree on the type of hazard, hazardous situation, and cause and effect, before the estimation of the risk elements and the risk evaluation proceeds.

NOTE ISO/TS 22559-1 includes global, essential safety requirements for lifts that can be used to provide samples of scenarios in addition to the examples given in Annex F of this International Standard.

4.5 Step 5 — Risk estimation

4.5.1 General

4.5.1.1 Up to step 4 (see 4.4), the scenarios have been formulated, including the hazard, hazardous situation and cause, as well as the potential effects that can result in harm. The possibility of harm has been identified but the level of the risk of harm remains to be determined. The risk estimation process is used to establish the level of risk elements and hence, the level of risk.

4.5.1.2 When determining elements of risk, and in particular, the probability of the occurrence of harm (see 4.5.4), only one lift shall be considered, rather than multiple installations of the same kind or the whole group of lifts. However, there are the following additional considerations.

a) When the elements of risk for one lift are being determined, where appropriate, the risks related to a group of interconnected lifts should also be considered for inclusion in the scenario.

EXAMPLE One moving escalator is feeding passengers onto a non-moving escalator (see also Example 4 of Annex F).

b) When elements of risk for one lift are being determined, statistics and experience derived from multiple installations or the whole lift group may be used.

EXAMPLE Statistics can indicate that out of 200 000 hydraulic lifts equipped with direct-plunger and in-ground cylinders, one incident per year occurs involving the lift car travelling at excessive speed or the lift car falling into the lift pit, due to the rupture of the cylinder. The probability of the occurrence of such an incident on a lift being analysed should be estimated as 1/200 000 per year or 1/10 000 during the 20-year life cycle of the lift.

4.5.1.3 Where a risk assessment team cannot reach consensus on the estimation of risk elements, the level of harm (see 4.5.3.1), or the level of probability (see 4.5.4.1), the scenario formulated in accordance with 4.4 should be re-examined for clarity and, if necessary, redefined (see also E.5).

4.5.2 Elements of risk

4.5.2.1 The risk associated with a particular scenario is derived from a combination of the following elements:

a) severity of harm;

b) probability of the occurrence of that harm, which can be a function of

1) the frequency and duration of the exposure of persons to the hazard,

2) the probability of occurrence of the scenario, and

3) the technical and human possibilities to avoid or limit the harm.

4.5.2.2 The elements are shown in Figure 3. Further details on elements of risk and the process of estimation of the level of severity of the possible harm and the level of probability of the occurrence of that harm are given in 4.5.3 and 4.5.4. Ultimately, the level of risk is determined in accordance with 4.5.6 and evaluated in accordance with Clause 5.

NOTE In many cases, these elements cannot be exactly determined, but can only be estimated. This applies especially to the probability of occurrence of possible harm.

Risk		**Severity**		**Probability of occurrence of the harm**
related to the considered hazard	is a function of the	possible harm that can result from the considered scenario	and	which can be a function of a) the frequency and duration of the exposure, b) the probability of harmful events, and c) the possibility of avoiding or limiting the harm.

Figure 3 — Elements of risk

4.5.2.3 In determining the level of probability of occurrence of the harm, it is essential to consider the combined probability of the occurrence of the hazardous situation, the cause and the effect. In determining the level of severity, only the severity of the effect (harm) is to be considered.

NOTE See Annex A.

4.5.3 Severity of harm

4.5.3.1 For the purposes of this risk assessment process, the level of severity of harm that can occur in a scenario should be estimated by considering possible effects on human life, property, or the environment, depending on the reason (see 4.1) and the subject (see 4.3) of the risk assessment, as being one of the following (see details in Table C.1):

a) level 1 – high;

b) level 2 – medium;

c) level 3 – low;

d) level 4 – negligible.

NOTE It can be necessary to modify the definitions of levels of severity given in Table C.1, depending on the reason for, and the subject of, the risk assessment (see 4.1 and 4.3).

4.5.3.2 When estimating the level of harm, the following should be taken into account:

a) the nature of what is affected, in terms of

   1) persons,

   2) property,

   3) environment, and

   4) other factors as appropriate;

b) the extent of harm that could occur on a lift to

   1) one person, and

   2) several persons.

4.5.4 Probability of occurrence of harm

4.5.4.1 Levels of probability

The probability of occurrence of harm can be estimated by taking into account the factors listed in 4.5.4.2 to 4.5.4.4. For this risk assessment methodology, the level of probability of occurrence of harm should be estimated as one of the following (see details in Table C.2):

a) level A – highly probable;

b) level B – probable;

c) level C – occasional;

d) level D – remote;

e) level E – improbable;

f) level F – highly improbable.

4.5.4.2 Probability of occurrence of a scenario

When estimating the probability of occurrence of a harmful event (cause and effect) and of persons being in hazardous situations when the event occurs, the following factors can be useful:

a) reliability of the lift components and the lift system as a whole (see 4.5.5.1); when assessing a process, such as servicing a lift or training service mechanics, the reliability and effectiveness of such processes should be considered;

b) statistical data;

c) accident history;

d) history of the nature and degree of harm;

e) comparison with similar lifting devices, or components, or processes.

NOTE 1 A cause that triggers a harmful event can be of technical, natural, or human origin.

NOTE 2 When estimating the probability of an occurrence, the regional statistical data can be taken into account, because the probability can be influenced by regional practices and regulations, such as those related to installation, maintenance, periodic testing and inspection of lift systems.

4.5.4.3 Frequency and duration of exposure to hazard

When estimating the probability of the occurrence of harm, the following factors should be considered.

a) The exposure of all persons working on or using the lift to the hazards relevant to a specific lift situation or event should be considered. The exposure of lift users or mechanics should be estimated in relation to one lift, not to multiple lifts (see 4.5.1.2).

b) Exposure and duration can be continuous.

   EXAMPLE A hazard that can have the effect of passengers tripping or falling when entering or leaving the lift car, exists even on lifts with perfectly level car-to-landing door sills.

c) Hazardous situations are always present, but exposure to a hazard can be very infrequent and of short duration, which implies a lower level of probability.

   EXAMPLE Relative movement of lift parts inside a lift well can present hazards to mechanics working on the top of the lift car, which could cause shearing and crushing effects. However, exposure to these hazards is infrequent and of short duration, because the mechanic works infrequently on the top of the car of a lift and because the car does not always move when the mechanic is on the top of the car. The possibility of harm to the mechanic exists only while the car is in motion, and only if the mechanic's body parts protrude beyond the perimeter of the top of the car. The mechanic's training and hazard awareness (see 4.5.4.4) can certainly reduce probability of the event and effect.

d) Exposure can also be less frequent, but the duration can vary.

   EXAMPLE If the strength of a landing door or its components is not sufficient to withstand any foreseeable misuse, such as a person hitting the closed door and breaking through when the car is away from the landing, there is a risk of a door breaking and a person falling into the well. Simultaneously, the person is exposed to the hazard with the possible effect of falling into the well and suffering serious harm. However, if the entrance remains unprotected after the door has been dislodged, the hazardous situation continues to exist, and potential users and passers-by are continuously exposed to the hazard of falling into the well.

e) In general, when estimating the frequency and duration of exposure, all relevant factors should be considered, such as the need for, and frequency of access to, potentially unsafe locations and the time spent therein.

   EXAMPLE A comparison can be made between access into the lift well for the purpose of servicing the lift and access to the lift car for the purpose of transportation.

4.5.4.4 Possibilities of affecting, avoiding or limiting harm

When estimating the probability of occurrence of harm, the following elements should be taken into account:

a) who the users of the lift are, whether

   1) members of the general public, including people of all ages, persons having physical disabilities, etc., or

   2) trained goods handlers, or trained fire-fighters, who are aware of specific risks;

b) who the persons who will perform any work on the lift are, whether

   1) skilled mechanics,

   2) inspectors,

   3) authorized persons with limited knowledge of the lift installation, or

   4) unskilled persons;

c) whether all necessary resources are given to persons in 4.5.4.4 a) and b) to assist them in avoiding or limiting harm, such as

   1) necessary training, work procedures and experience,

   2) control over car movement,

   3) means of risk awareness, such as warning signs and indicating devices,

   4) adequate working space, and

   5) procedure and means for escape from the hazardous situation;

d) whether all human factors have been adequately considered, such as

   1) interaction of persons with the lift equipment,

   2) interaction between persons, typically when performing complex servicing tasks,

   3) psychological aspects, such as complexity of tasks and claustrophobia,

   4) ergonomic effects, such as working space,

   5) capacity of persons to be aware of risks in a given situation, depending on their training, experience and ability,

   6) temptations to deviate from prescribed and necessary safe working practices,

   7) likelihood that a person or persons will not act as anticipated, and

   8) whether protective measures provided to mitigate one hazard can cause other hazards;

   EXAMPLE A guard railing preventing mechanics from falling off the top of the lift car could crush them if the car travels upwards, allowing the top of the railing to come close to the well ceiling.

e) the consideration that training, experience and ability can affect the risk, but none of these factors should be used as a substitute for hazard elimination or risk reduction by design or safeguarding where these safety measures can be implemented.

4.5.5 Further factors to be considered

4.5.5.1 Reliability of safety functions

Risk estimation shall take into account the reliability of components and systems (see Table B.3). It shall identify the circumstances that can result in effect and ultimately in harm, such as component failure, power failure and electrical disturbances.

When more than one safety-related device contributes toward a safety function, the selection of these devices shall have consistent performance when considering their reliability (see also 4.3.2.2).

When protective measures include work organization, appropriate behaviour, warnings, application of personal protective equipment, skill, or training, the relatively low reliability of such measures compared to proven technical protective measures shall be taken into account in the risk estimation.

4.5.5.2 Possibility of defeating or circumventing protective measures

Risk estimation shall take into account the possibility of defeating or circumventing protective measures. The estimation shall also take into account the incentive to defeat or circumvent protective measures.

EXAMPLE Protective measures can slow down work on the lift, such as troubleshooting, or can interfere with any working method preferred by the worker. Furthermore, a protective measure can be difficult to use.

The possibility of defeating a protective measure depends on both its design characteristics and the type of protective measure, such as an adjustable or removable guard or a programmable rather than non-programmable safety device.

4.5.5.3 Ability to maintain protective measures

Risk estimation shall consider whether the protective measures can be maintained in the condition necessary to provide the required level of protection.

NOTE If a protective measure cannot easily be maintained in its correct working order, this can encourage people to defeat or circumvent the protective measure to allow continued use of the lift without needed repair.

4.5.5.4 Effects of foreseeable misuse, vandalism and human error

Risk estimation shall take into account the susceptibility of a lift or its components to acts of foreseeable misuse or vandalism, based on experience related to lifts in general or to specific types of lift location. This applies to the risk estimation of a design, conformity assessment process, or any other process. Acts of foreseeable misuse or vandalism include forcible entry, overloading, removing parts, lighting fires, spraying paint, hosing water into the well and smashing doors and leaving the well entrance unprotected.

The likelihood of human error shall be taken into account in any estimation, e.g. forgetting to carry out a safety procedure.

4.5.6 Level of risk

The risk level is established by combining the levels of severity (4.5.3.1) and probability (4.5.4.1), as illustrated in Table D.1.

EXAMPLE If the level of severity is estimated as level 1 and the level of probability as level B, according to Table D.1, the level of risk is “1B”.

5 Step 6 — Risk evaluation

5.1 Once the level of risk is estimated, evaluation of the risk is to be carried out to determine if any protective measures need be taken to reduce the risk. The risk is evaluated by identifying the corresponding risk group based on the estimated risk level.

5.2 The risk levels are grouped as shown in Table 1 (see details in Table D.2).

Table 1 — Measures for various risk levels

Risk group	Measures to be taken
I	Protective measures are required to reduce risk.
II	Review is required to determine whether any further protective measure is appropriate to reduce risk, taking into account the practicability of the solution and societal values.
III	No action is required.

5.3 When selecting the risk to be evaluated, the risk assessment team (see 4.2) shall select the highest level of risk, not necessarily the highest severity level.

EXAMPLE The scenario that leads to a risk estimated at level 2C (Risk group I) is a higher risk than 1E (Risk group II). The protective measures with respect to the 2C risk level should be considered first, even though the risk level estimated at 1E has the higher level of severity; however, risk 1E still must be addressed (see Table D.2).

NOTE Table D.3 is identical to Table D.1 in format, but has blank fields. It is provided to assist the risk assessment team in assessing the acceptability of level of risk.

6 Step 7 — Has the risk been sufficiently mitigated?

6.1 If the risk evaluation in Clause 5 indicates that the risk belongs to Risk group I or II, then appropriate protective measures shall be selected (Clause 7).

6.2 Once the protective measure is implemented, the risk assessment process shall be repeated, starting with step 4 (see Figure 1), to verify that

a) risk has been sufficiently reduced,

b) no new risk has been created by implementation of the protective measure, and

c) any existing residual risk does not require further reduction.

6.3 Very often, the protective measure reduces the probability, but does not eliminate the hazard. In such circumstances, the probability is reduced, but the severity remains the same.

NOTE 1 See Example 2 of Annex F. After corrective action, the severity remains at 1 because the falling height remains the same. Probability is reduced because the gap is smaller.

If a protective measure does eliminate the hazard, then the severity, as well as the probability, is reduced to 4F.

NOTE 2 See Example 3 in Annex F. In this example the corrective action eliminates the hazard, thus reducing the levels of severity and probability to the lowest levels, indicated by 4F.

6.4 If new, potentially hazardous scenarios are identified during this iterative process, such scenarios should be added to the original list of scenarios. The risk analysis and assessment relevant to the scenario should be carried out.

NOTE See Example 2, Case 2.1, Option 1 and also Case 2.2 in Annex F.

7 Step 8 — Reduction of risk — Protective measures

7.1 The process of risk reduction shall be carried out as follows.

a) Eliminate the hazard, where possible, by revisions to the design of the lift or by substitution of lift components.

b) If the identified hazard cannot be eliminated in accordance with a), further design-related measures should be taken to reduce the risk. These measures include the following:

1) redesigning equipment, so as to increase its reliability or reduce exposure;

EXAMPLE Measures to increase reliability include increasing safety factors and introducing redundancy to components prone to failure, such as electromagnetic relays, electronic and software components, redundant braking systems and life cycle tests.

2) reducing frequency and/or duration of exposure to hazard;

3) altering procedures for use, service or cleaning, as the case may be;

4) adding protective or safety devices to act should a lift component fail;

EXAMPLE Protective devices include devices similar to safety gears, buffers, safety brakes and people detectors.

5) adding guards to separate persons from hazardous equipment or spaces.

EXAMPLE Such guards include well enclosures to separate lift equipment from areas accessible to the general public, and covers on rotating or moving parts to protect mechanics from inadvertently coming into contact with them.

c) If the identified hazard cannot be eliminated or sufficiently mitigated in accordance with 7.1 a) or b), inform the users of the device, system, or process of the residual risks. These measures include the following:

1) information;

2) need and scope of training;

3) adding warning signs;

4) use of personal protection equipment.

d) Eliminate or minimize the probability of defeating or circumventing protective measures such as guards and safety devices.

7.2 It is emphasized that the additional protective devices, personal protective equipment and provision of information to users should not be used as a substitute for design improvements in accordance with 7.1 a).

8 Documentation

8.1 The process and results of the risk analysis and assessment shall be written down using the templates given in Annex A and Table D.3 or a format that, at a minimum, contains the data required in Annex A and Table D.2.

8.2 The documentation should include the following:

a) the reason for the risk assessment process (4.1);

b) the team moderator and members (4.2);

NOTE Data required in 8.2 a) and b) can be recorded in a document other than documents compiled in accordance with Annex A and Table D.3.

c) the subject of the risk assessment (4.3);

d) the records of scenarios, including hazard, hazardous situation, harmful event, effects and harm and estimation of risk elements, before and after the implementation of protective measures, if any (4.5);

e) the evaluation of risk before and after the implementation of protective measures (see examples in Annex F), using criteria set in Annex D and Clause 5;

f) the assessment of results of the risk evaluation and the need for further reduction of the risk (Clause 6);

g) all considered and implemented protective measures and the residual risks (Clauses 6 and 7);

h) any reference data used and the sources of the data, e.g. codes and standards, historical information, statistics, drawings, design calculations, manufacturers, relevant records of accidents and levels of harm;

i) any assumptions made in the course of the process of setting scenarios or conducting the risk estimation and assessment;

j) a copy of Table D.3, if used by the team, to record risk levels (see Table D.2) estimated before and after implementation of protective measures.

Annex A
(normative)

Risk assessment template

Table A.1 — Risk assessment template

Purpose [a] and subject: ____________________ **Moderator [a]:** ______________________________ **Date:** ______________________________

Case number	Scenario			Estimation of risk elements		Protective measures (risk reduction measure)	After protective measures		Residual risk
	Hazardous situation	Harmful event							
		Cause	Effect	S [b]	P [c]		S [b]	P [c]	
	Comments								
	Comments								
	Comments								
	Comments								

[a] Purpose, team moderator and members may be recorded in a separate document.

[b] S — Levels of severity of the harm (see 4.5.3):
1 — High 2 — Medium 3 — Low 4 — Negligible

[c] P — Level of probability of occurrence of harm (see 4.5.4):
A — Highly probable B — Probable C — Occasional D — Remote E — Improbable F — Highly improbable

Annex B
(informative)

Quick references to hazards (Table B.1), hazardous situations (Table B.2), causes (Table B.3), effects (Table B.4) and harm (Table B.5)

Table B.1 — Examples of hazards

Type of hazard	Details and examples
B.1.1 Mechanical	**a) Specific mechanical features** — mass and velocity (kinetic energy of elements in controlled or uncontrolled motion) — acceleration, force — inadequate mechanical strength — potential energy or accumulated energy inside an elastic element (e.g. spring), gases/liquids under pressure (e.g. hydraulic or pneumatic)
	b) Mechanical part(s) — moving or rotating parts and relative movement of moving parts — shape (sharp, pointed, rough, etc.)
	c) Gravity — mass and stability — collapse of element supporting equipment or persons — uneven or slippery area — elevated unguarded area — floor obstruction on walking/working area
1.2 Electrical	— live conductors — live machine elements from loss of insulation — electrostatic phenomena
1.3 Radiation	— low frequency, radio frequency, microwave, X-ray and gamma ray — laser/infrared, visible and ultraviolet light
1.4 Chemical	— hazardous (harmful, toxic, corrosive) — combustible or flammable
1.5 Neglect of ergonomic principles	— inadequate lighting — inadequate visibility (poor layout of controls) — difficult access to, or inadequate height of, work space
1.6 Fire	— within driving or control equipment — within car or well

Table B.2 — Examples of hazardous situations

Type of hazardous situation; presence of hazard to which persons can be exposed	Details and examples
B.2.1 Mechanical hazards	**a) General mechanical** Persons are in a location or situation where it is possible for them to — be exposed to energy sources involving mass and velocity and the kinetic energy of elements in controlled and uncontrolled motion, EXAMPLE Persons at the floor close to the unenclosed lift well in which lift car and counterweight travel. — come into contact with a hazardous (sharp, pointed, etc.) shape, — be exposed to various hazards due to mechanical failure of a mechanical component, or — approach sources of accumulated energy in the form of elastic elements (springs) or gases/liquids under pressure (hydraulic, pneumatic).
	b) Moving part(s) Persons are in a location where it is possible to come into contact with zones of entanglement, shearing, trapping, crushing/impact and friction/abrasion.
	c) Gravity Persons are in a situation where they are or could be — at a height, — near an elevated load or non-fixed component or tool, — near an opening, such as a car top, hole in the machine room floor, or open well doors when the car is away, or — on slippery, uneven, cluttered ground, floor, or area.
2.2 Presence of electrical hazards	Persons are in a location or situation where there is a possibility for persons to: — come into contact with live components (direct contact); — access machines being electrified, e.g. following an insulation failure (indirect contact); — approach parts under high voltage; — come into contact with elements carrying electrostatic charges.
2.3 Presence of thermal hazards	Persons are in a location or situation where there is a possibility of exposure to a hot or cold environment or surface. This could be as a user in the car or a worker in a cold or hot machine room, or a person touching a hot component.
2.4 Presence of radiation hazards	Persons are in a location or situation where they could be exposed to a hazardous radiation source.
2.5 Presence of chemical hazards	Persons are in a location or situation where there is a source of ignition by flammable dusts, gases, or vapours generated by materials or products.
2.6 Presence of hazards generated by neglect of ergonomic principles	Persons need to have an access lift to ride, or workers need to have access to equipment for repairs, but — the lift access entrance is narrow or inadequately lit, — the lift interior is inadequately lit, visibility of controls is insufficient for lift users, or — workers can not access or reach equipment to do work from the working area.

Table B.3 — Examples of causes (component of harmful events)

Causes	Details and examples
B.3.1 Events involving general mechanical hazardous situations	**a) Breaking or failure of mechanical parts** — any drive component, e.g. gear, shaft, drive sheave, brake, suspension means, hydraulic jack, or valve. — car or well entrance doors, their elements, door mechanical lock, etc. — lift car floor — lift car or well enclosures, enclosure lining, light fixtures, car or counterweight guiding means
	b) Tipping, overturning, or falling of parts or tools — machine tipping or overturning — falling tools used by mechanics
	c) Braking or failure of mechanical safety part The parts provided to stop the car safely should another lift part fail, such as — car or counterweight safety or mechanical governor, — emergency brake, — buffer, and — door lock or interlock.
3.2 Events involving moving parts, components	**a) Unexpected or unintended start of car movement** Due to failure of a component such as — a safety device (interlock or door contact), — safety-related circuit, — drive component (brake, shaft), or — motion control system (failure of a relay, solid state device, software, anomaly in logic, outside EMI). EXAMPLE Car starts to move when landing door is open as a result of door interlock or its circuit's failure, or due to the failure of the brake to hold car at the landing.
	b) Car accelerates beyond its rated speed Due to failure of a component, such as — motion control system, or — slowdown and stopping system (brake, shaft).
	c) Car accelerates or decelerates abruptly Due to failure of a component such as — motion control system, or — brake.
	d) Unexpected start of lift while a person is working in well or machine room Due to various mechanical or control failures mentioned in a) to c).
3.3 Event involving or instigating gravity issues	— slippery floor (possibility of a person tripping and falling on the floor) — well door left open (possibility of a person falling into the lift well) — elevated working platform railing fails to hold worker (possibility of falling) — falling matter or material (e.g. tool or lift part)

Table B.3 (*continued*)

Causes		Details and examples
3.4	**Event involving electrical hazards**	— person comes into contact with a live element (direct contact) — person comes into contact with a component that is electrified due to insulation defect — person comes into contact with a component that is electrostatically charged
3.5	**Event involving thermal hazards**	— car stops between landings, leaving passenger exposed to a hot or cold environment — mechanic in the machine room or inside the well is exposed to a hot or cold environment while performing tasks
3.6	**Event involving chemical hazards**	— person comes into contact with or inhales fire, smoke, fluids, gases, fumes, or dust EXAMPLE Mechanic using cleaning fluid within confined space of lift car.
3.7	**Event involving ergonomic issues**	EXAMPLE Person entering working space that is inadequate to perform the intended work.

Table B.4 — Examples of possible effects

Effects	Example of effects		
B.4.1 Effect of mechanical origin	— abrasion — being caught by — being dragged — burning — crushing	— cutting — entanglement — impact — projection — pulling out	— puncture — severing — shearing — stabbing
4.2 Effect linked to gravity	— collapse — crushing — falling — jamming	— lowering — slipping — slumping	— suffocation — tripping — wedging

Table B.5 — Examples of effects in terms of harm

Harm	Example of harm		
B.5.1 Harm from mechanical causes	— fracture — sprain/strain — cut/laceration — amputation — open wound	— puncture/stabbing — abrasion/scratch — bruise — contusion	— irritation — friction burn — multiple injuries — death
5.2 Harm from electrical causes	— electric shock (discomfort)	— electric shock (severe injuries)	— electrical burn — electrocution
5.3 Harm from thermal causes	— tissue damage — hypothermia	— heatstroke — suffocation	
5.4 Harm from chemical causes	— damage to health — death	— burns (chemical or fire)	— smoke or fume inhalation
5.5 Harm caused by neglect of ergonomics	— physiological effects (e.g. musculoskeletal disorder) resulting, for example, from awkward postures, excessive or repetitive effort	— psycho-physiological effects (effects of mental overload, mainly stress) — claustrophobia	— injuries resulting from untimely operation, itself caused by human error promoted by a poor conception of the “man-machine” interface

Annex C
(normative)

Estimation of risk elements — Severity (Table C.1) and probability (Table C.2)

C.1 The levels of severity described in 4.5.3.1 and in Table C.1 are given to provide approximate quantitative measures of the severity of harm. It is recognized that in some cases the users of this methodology are not qualified to determine the actual harm in terms of injuries that a given individual can suffer in a particular harmful event, but they are able to quantify the estimated level of possible harm based on the technical and physical characteristics of the effect.

NOTE See examples in Annex F.

The descriptions of levels of severity of harm in Table C.1 and probability levels in Table C.2 (see 4.5) are given for guidance when risk assessment is performed in relation to lifts that are intended for general use and transportation. In special cases, such as the use of lifts by fire-fighters or by hospital personnel, the description of levels of severity and probability will need adjustment.

Table C.1 — Levels of severity

Identify level of severity	Description
1 — High	Death, system loss, or severe environmental damage
2 — Medium	Severe injury, severe occupational illness, or major system or environmental damage
3 — Low	Minor injury, minor occupational illness, or minor system or damage
4 — Negligible	Does not result in injury, occupational illness, or system or environmental damage

C.2 The levels of probability specified in 4.5.4.1 are described in Table C.2 to give approximate quantitative measures of the probability of the occurrence of harm in a specific scenario.

Table C.2 — Levels of probability

Identify level of probability	Description
A — Highly probable	Likely to occur frequently in the life cycle
B — Probable	Likely to occur several times in the life cycle
C — Occasional	Likely to occur at least once in the life cycle
D — Remote	Unlikely, but may possibly occur in the life cycle
E — Improbable	Very unlikely to occur in the life cycle
F — Highly improbable	Probability cannot be distinguished from zero

Annex D
(normative)

Risk estimation and evaluation

Table D.1 (normative) specifies the levels of probability and severity in risk estimation and evaluation, while Table D.2 (normative) specifies the grouping of risk evaluation and measures to be taken. Table D.3 (informative) assists the risk assessment team to assess and record the acceptability of level of risk.

Table D.1 — Risk estimation and evaluation (see 4.5.6 and Clause 5)

Level of probability	Level of severity			
	1 — High	2 — Medium	3 — Low	4 — Negligible
A — Highly probable	1A	2A	3A	4A
B — Probable	1B	2B	3B	4B
C — Occasional	1C	2C	3C	4C
D — Remote	1D	2D	3D	4D
E — Improbable	1E	2E	3E	4E
F — Highly improbable	1F	2F	3F	4F

Table D.2 — Risk evaluation (Clause 5)

Risk group	Risk levels	Measure to be taken
I	1A, 1B, 1C, 1D, 2A, 2B, 2C, 3A, 3B	Protective measures required to reduce the risks
II	1E 2D, 2E 3C, 3D 4A, 4B	Review is required to determine whether any further protective measure is appropriate, taking into account the practicability of the solution and societal values [a]
III	1F 2F 3E, 3F 4C, 4D, 4E, 4F	No action required

[a] Society will not tolerate some specific risks. Further measures can make use, service, etc. of the lift impractical or impossible.

Table D.3 — Template for recording risk profiles of specific scenarios

Indicate: This risk profile is before __________ or after _________ implementation of protective measures					
Level of severity		1	2	3	4
Probability level	A				
	B				
	C				
	D				
	E				
	F				

Level of probability		Level of severity
A — Highly probable	D — Remote	1 — High
B — Probable	E — Improbable	2 — Medium
C — Occasional	F — Highly improbable	3 — Low
		4 — Negligible

This template in Table D.3 is provided for users (team members) of this International Standard to assist in the risk estimation process, by entering the scenario case number (see the first column in Table A.1 of Annex A) into the field corresponding to the estimated levels of severity and probability, in order to indicate the risk level before any protective measures are implemented. If the criteria set out in Tables D.1 and D.2 indicate that the level of risk needs further mitigation, protective measures are implemented and new risk estimation is carried out. The users should then use a new copy of this template to enter the scenario case number into the field corresponding to the newly estimated levels of severity and probability, in order to verify that the risk has been sufficiently mitigated.

Annex E
(informative)

Role of the team moderator

E.1 General role of moderator

E.1.1 Skilful moderation of the risk assessment team is very important for the results of a risk assessment. Poor team moderation can dramatically reduce the effectiveness of the risk assessment process.

E.1.2 The team moderator should have good knowledge and understanding of the methodology set out in this International Standard. In addition, the moderator should

a) have an overall understanding of the product or process being assessed, but need not necessarily have expertise in all aspects of the subject being analysed,

b) have facilitating abilities, including good questioning skills,

c) be able to assume an impartial view, free of any biases.

E.1.3 The moderator's duties and responsibilities are as follows:

a) form a team that is balanced, in accordance with 4.2.2;

b) ensure that the team members understand and accept the rules of the risk assessment process set out in this International Standard;

c) remain objective and guide the team through a disciplined and focused risk assessment process;

d) act as facilitator rather than participant in the debates of the team, in other words, to facilitate the work of the team, without bias; when discussing topics and expressing opinions, the moderator may express his or her own opinion concerning the topic, but this shift from the moderator role should be an exception and should be indicated clearly to the team;

e) stimulate in-depth discussion by the members, which is accomplished by using a thought-provoking process of questioning when developing the scenarios and reaching consensus;

f) ensure that any scenario (see 4.4.3), including assumptions, if any, are clearly formulated and understood;

g) ensure that the teamwork and decision-making process are properly recorded (see Clause 8);

h) ensure that the estimation and evaluation of the risk (see 4.5 and Clause 5) and relevant decisions are made in accordance with consensus principles.

E.2 Introduction for risk assessment session

E.2.1 General

It is important that the risk assessment team members know the reason (see 4.1) and the subject (see 4.3) of the risk assessment so that they can focus on the work to be done. Moreover, they should feel comfortable and understand the goals to be achieved. Some aspects to consider are described in E.2.2 to E.2.4.

E.2.2 Introduction

The team moderator should

a) explain the purpose of the meeting (see 4.1),

b) ask for each team member's name, professional background in all relevant fields, and current field of employment and function,

c) describe the subject to be analysed and assessed (see 4.3).

E.2.3 Risk assessment methodology

The team moderator should verify the knowledge and understanding of the team members [see E.1.3 b)] of the methodology set out in this International Standard before the team starts to work. This can include a brief review, a more in-depth review, or training related to the following subjects:

a) terminology (Clause 2);

b) the concepts of safety and risk assessment (Clause 3);

c) the reason for conducting the risk assessment and the subject of it, including additional factors to be considered (4.3);

d) identification of scenarios (4.4), in particular the meaning, identification and determination of hazards, hazardous situations, and causes and effects, including harm (see Annex B);

e) elements of risk and the concept of risk estimation, with special attention to the estimation of the level of severity of harm (4.5.3) and the level of the probability of occurrence of harm (4.5.4); before the level of probability is estimated, it is important that the members understand the need to take into account all elements of probability, such as the frequency and duration of exposure of persons to the hazard, probability of occurrence of the scenario, and possibility of limiting or avoiding harm;

f) concept of, and approaches to, risk mitigation (Clause 7);

g) the need to record the details of the whole process (Clause 8).

E.2.4 What is expected of team members

The role and responsibility of team members and the moderator (see 4.2) should be established, including the following:

a) use of the process and members' experience to identify the hazards and assess the risk;

b) need to act as individual and independent experts.

E.3 Guidelines for the risk assessment session

The moderator should set and obtain agreement on the guidelines for conducting the sessions. The guidelines should

a) assign a team member to take notes of the process,

b) focus team members on the task of identifying and assessing the risks.

E.4 Conducting the risk assessment session

Moderating the risk analysis session is a challenging task. The moderator should constantly be alert, ask questions and listen carefully to the discussion of the team, so that he or she can summarize the findings and formulate the scenarios. Some recommendations are as follows.

a) Start slowly, with clear instructions and easy-to-understand explanations.

b) Be aware that in the beginning of the meeting, it takes longer to formulate scenarios than later, when the team gets used to it.

c) Stay calm and keep the process moving.

d) Control and summarize long discussions, particularly about risk reduction measures.

e) Begin to build team spirit right from the start by involving all team members and acknowledging their contributions.

f) Summarize discussion periodically to keep the team focused and keep it on track, e.g. before a scenario is formulated, to make sure everyone is in agreement.

g) Focus on one scenario at a time and ask the team members to take note of their own ideas about other scenarios to be addressed later.

h) Build consensus where there are opposing opinions.

i) Try to find and summarize the points of agreement in each view.

j) Avoid voting, averaging and bargaining as much as possible, unless consensus cannot be reached.

k) Help the team to recognize and enjoy the progress made during the session.

E.5 Estimating scenarios

E.5.1 After a scenario (4.4) is formulated and recorded, the severity of the effect and the probability that the scenario will occur are estimated (4.5). The estimation is done according to the definitions of levels of severity in Table C.1 and levels of probability in Table C.2.

E.5.2 Usually, consensus can easily be reached on the estimation of the severity of harm, whereas the estimation of the probability level can be more challenging. Some practical guidelines to assist in the probability estimation are as follows.

a) Ask the team if there is a general feeling that something should be done to reduce the risk or not; choose the grading and write down the main reasons.

b) Agree from the beginning of the risk assessment session to choose the higher risk in case of doubt.

c) Find new aspects influencing the level of probability, recapitulating all components of probability set in 4.5.4 and 4.5.5, or review each discussed aspect again and assess it individually; then summarize the findings to estimate the probability.

d) Postpone the estimation or assessment and come back to it later.

e) If an agreement cannot be reached, ask each team member to vote, average the results, or go with the majority; note that the second vote can sometimes bring the group closer; however, the voting approach should be avoided (see E.5.3).

E.5.3 Where consensus cannot be reached, the moderator should work with the team to determine the cause. Causes include lack of understanding of the process, inadequate determination of the purpose and subject of analysis or scenario components, or lack of understanding of all components of probability. The moderator may offer an alternative approach.

EXAMPLE When a team cannot reach consensus on probability level, the moderator can explore whether the team can at least agree that some corrective action should be taken.

E.6 Closing the risk assessment session

Guidelines for closing the risk assessment session include the following.

a) Summarize briefly the most important findings and achievements.

b) Ensure that the details of all that was done during the session are noted down in accordance with Clause 8.

c) State the further steps to be taken.

d) Finalize the report and send it for review by the team members.

Annex F
(informative)

Examples of a risk assessment and protective measures

The following examples are intended to demonstrate the methodology. They do not necessarily reflect complete comprehensive solutions as required by current safety codes or standards.

EXAMPLE 1 Illustration of two approaches when estimating severity of harm (see 4.4.2.4.3).

EXAMPLE 2 Mitigation of risk by revision to design, adding protective measure and checking residual risk level.

EXAMPLE 3 Changes in severity and probability levels when hazard is removed or mitigated.

EXAMPLE 4 Verification of safety of an escalator system design — drive chain.

Example 1 — Illustration of two approaches when estimating severity of harm (See 4.4.2.4)

Purpose: *To illustrate two approaches when estimating severity of harm*

Subject: *Automatic closing of lift doors* **Moderator:** Not applicable to this example **Date:** Not applicable to this example

Case number	Scenario			Estimation of risk elements		Protective measures (risk reduction measure)	After protective measures		Residual risk
	Hazardous situation	Harmful event		S [c]	P [d]		S [c]	P [d]	
		Cause	Effect						
1	Hazard: Mechanical — kinetic energy [B.1.1 a)]								
1.1 [a]	Automatic door having high mass closes at high speed giving high kinetic energy Elderly person entering or exiting car	Door closes while the person is in the door path	1.1 injuries not stated – door impacts the person with high kinetic energy, – knocks the elderly person onto floor.	2	D	Reduce the speed of doors to reduce the kinetic energy at impact to the level that would not knock a weak person onto the floor.	2	E	Even a low kinetic energy may knock over a very weak person.
1.2 [b]			1.2 injuries specified – door impacts the person with high kinetic energy, – knocks the elderly person onto floor, – the elderly person's hip fractures	2	D	Provide reliable sensing devices to stop and reopen doors when a person is anywhere in the door path.	2	E	The sensing device fails and the door still hits the person with full energy.

[a] In Case 1.1, the level of severity is estimated based on the description of the effect.

[b] Case 1.2 differs in that the effect in terms of injuries is also described. The risk has been mitigated to the same level by two different protective measures.

[c] S — Levels of severity of the harm (see 4.5.3):
1 — High 2 — Medium 3 — Low 4 — Negligible

[d] P — Level of probability of occurrence of harm (see 4.5.4):
A — Highly probable B — Probable C — Occasional D — Remote E — Improbable F — Highly improbable

Example 2 — Mitigation of risk by revision to design, adding protective measure and checking residual risk level

Purpose: *To illustrate mitigation of risk by revision to design, adding protective measure and checking residual risk level*

Subject: *Safety of person working on the top of the car* **Moderator:** Not applicable to this example **Date:** Not applicable to this example

Case number	Scenario			Estimation of risk elements		Protective measures (risk reduction measure)	After protective measures		Residual risk
	Hazardous situation	Harmful event							
		Cause	Effect	S [c]	P [d]		S [c]	P [d]	
2	Hazard: Falling hazard (gravity)								
2.1 [a]	Mechanic works on top of car 30 m above pit. There is a 1 m space between edge of car top and well wall.	Mechanic steps back beyond edge of top of car.	Mechanic falls off edge of top of car into pit.	1	D	2.1 Mitigation of falling hazard: Option 1: Reduce the 1 m gap to 100 mm so mechanic cannot fall between car and wall.	1	F	2.1.1 After corrective action, the severity remains 1 because the falling height remains the same. Probability is reduced because the gap is smaller. No action required regarding falling hazard. However, new risk is created in that the mechanic can fall, twist and injure trapped foot (see Case 2.2).
						Option 2: Install a 1,1 m high guardrail around edge of top of car to deter fall from edge.	1	F	2.1.2 No action required regarding falling hazard. NOTE With respect to any new hazard caused by guardrail, see commentary below.

Example 2 (*continued*)

Case number	Scenario			Estimation of risk elements		Protective measures (risk reduction measure)	After protective measures		Residual risk
	Hazardous situation	Harmful event							
		Cause	Effect	S [c]	P [d]		S [c]	P [d]	
New hazard: Trapping of foot (see residual risk of Case 2.1 and Option 1)									
2.2 [b]	Mechanic is working on top of car. There is 100 mm gap between edge of car top and well wall.	Mechanic steps back beyond edge of top of car. His or her foot becomes trapped.	Mechanic falls, twists and injures trapped foot.	2	E	Training is required to make mechanics more aware of foot entrapment issues.	2	E	No further action is required. The severity level is at 2 because a serious injury can occur. The probability level is assessed to be E, which is reduced from the original D in Case 2.1 as the space for stepping into has been reduced.

a The first obligation of the team is to eliminate or mitigate the hazard, if feasible. Two options are proposed to address the falling hazard. Option 1 creates a foot trapping hazard for which a new scenario is given in 2.2. In Option 2 it is assumed that there is sufficient clearance overhead so as to not create any new hazard when the car reaches its utmost position. Neither option eliminates the falling hazard hence the severity remains at level 1 [c] however, the probability is reduced to level F [d], thus mitigating the risk of falling to an acceptable level.

b The scenario in 2.2 is formulated to find out if the new risk needs further mitigation. The probability of stepping back and having the foot trapped and hurt is less than the probability of the incident in 2.1, stepping back, losing balance and falling into the well.

c S — Levels of severity of the harm (see 4.5.3):
1 — High   2 — Medium   3 — Low   4 — Negligible

d P — Level of probability of occurrence of harm (see 4.5.4):
A — Highly probable   B — Probable   C — Occasional   D — Remote   E — Improbable   F — Highly improbable

Example 3 — Changes in severity and probability levels when hazard is removed or mitigated

Purpose: *To illustrate changes in severity and probability levels when hazard is removed or mitigated*

Subject: *Door model — Sharp edges* **Moderator:** Not applicable to this example **Date:** Not applicable to this example

Case number	Scenario			Estimation of risk elements		Protective measures (risk reduction measure)	After protective measures		Residual risk
	Hazardous situation	Harmful event		S [c]	P [d]		S [c]	P [d]	
		Cause	Effect						
3	Hazard: Mechanical — sharp edges (cutting hazard)								
3.1	Landing door has a very sharp edge on landing side. Passenger approaches elevator from landing side while door is closing.	Passenger places hand on sharp edge to stop door closing.	Hand injury (cuts)	3	B	Option 1 [a]: Eliminate sharp edge by design. Option 2 [b]: Detect presence of a hand in door path and re-open door automatically.	4 3	F C	Cutting hazard removed. Cleaning or working person can still be injured on sharp edges.
3.2	Landing door has very sharp edge on landing side. Person cleaning or working in presence of door.	Person accidentally comes into contact with sharp edge.	Hand injury (cuts)	3	C	Eliminate sharp edge by design.	4	F	Cutting hazard removed. (Option 2 of 3.1 is not acceptable.)

a Option 1 eliminates the hazard, reducing the levels of severity and probability to the lowest levels (indicated by 4F).

b In practice, Option 2 is not an effective protective measure. Firstly, it addresses the cause rather than the hazard, leaving the same level of severity (indicated by 3). Probability is reduced to C. Secondly, the residual risk is that the detection device is not effective when the door is fully open and cleaning personnel or skilled personnel working at the door can still be injured. Considering social values, Option 2 is not acceptable.

c S — Levels of severity of the harm (see 4.5.3):
1 — High 2 — Medium 3 — Low 4 — Negligible

d P — Level of probability of occurrence of harm (see 4.5.4):
A — Highly probable B — Probable C — Occasional D — Remote E — Improbable F — Highly improbable

Example 4 — Verification of safety of an escalator system design — drive chain

Purpose: *To illustrate need for addressing hazards that could arise from component failure* [see 4.5.1.2 a)]

Subject: *Escalator drive chain* **Moderator:** Not applicable to this example **Date:** Not applicable to this example

Case number	Scenario			Estimation of risk elements		Protective measures (risk reduction measure)	After protective measures		Residual risk
	Hazardous situation [a]	Harmful event: Cause	Harmful event: Effect	S [b]	P [c]		S [b]	P [c]	
4.1	Passengers are riding on an escalator.	The main drive chain that transmits the driving force to the step chain breaks due to (e.g.) inappropriate dimensioning or manufacturing fault.	The escalator accelerates downwards. Passengers fall at the lower landing, causing injuries.	2	D	Use a duplex chain with a safety factor against breakage of 5.	2	E	There is still the possibility of a main drive chain breakage, but the probability is reduced.
4.2	Passengers are riding on an escalator equipped with a duplex chain.	The duplex drive chain that transmits the driving force to the step chain breaks due to (e.g.) inappropriate dimensioning or manufacturing fault.	The escalator accelerates downwards. Passengers fall at the lower landing, causing injuries.	2	E	Use auxiliary brake acting directly on the main drive on the step band.	2	F	The auxiliary brake will stop the step band if the main drive chain breaks. No further action required.

[a] Elimination of the hazard is not possible due to gravity. Therefore, it is necessary to mitigate the cause. This is done by adding a duplex chain. Assessment of severity and probability is 2E, which requires further review. Further review is carried out in Case 4.2 and a protective measure results in the addition of an auxiliary brake which reduces the risk to 2F.

[b] S — Levels of severity of the harm (see 4.5.3):
1 — High 2 — Medium 3 — Low 4 — Negligible

[c] P — Level of probability of occurrence of harm (see 4.5.4):
A — Highly probable B — Probable C — Occasional D — Remote E — Improbable F — Highly improbable

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