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Guide to the implementation and use of the barrier indicator

Report

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ABSTRACT

The guide describes how to use the «barrier indicator» in construction projects. The indicator measures the availability of barriers in safety-critical construction activities and the results are presented as a percentage of full availability. Safety-critical activities are characterized by the fact that they involve the handling of large amounts of energy with the potential to disable or kill people. The use of the indicator provides site management and the HSE organization with the necessary information to manage the risk of severe harm in production. The guide presents the procedure for establishing and using the barrier indicator. It also introduces the underlying theory. A set of checklists that constitute a vital tool in the use of the barrier indicator can be found in the appendix. The checklists and the underlying method for barrier analysis also have other uses within the HSE discipline such as accident investigations and risk analyses. They provide important elements in the management of barriers against severe accidental harm through the phases of a project's life cycle.

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Preface

This guide aims primarily to establish a common practice for the use of the barrier indicator on building and construction projects. The purpose of using the method is to achieve lasting improvements in the prevention of severe injuries due to adverse events. Such incidents are characterized by the fact that they occur in activities where large amounts of energy are handled with the potential to kill or disable persons.

The guide describes the use of the barrier indicator. This includes quantifying the extent to which necessary barriers are in place and function properly in the focused activities. Input data to this quantification consists of results of checks of the availability and quality of the individual elements that make up each barrier. This makes it possible to direct preventive actions to the areas where barriers are unavailable or do not meet required standard.

The barrier indicator is made up of a set of underlying methods and tools that have other uses as well. The guide highlights such uses as investigations into the causes of barrier failure in undesirable incidents, the design of measures to remedy specific risks identified in connection with planning and design, and review of the safety standard prior to the start of critical activities.

The guide also describes a systematic approach for the management of barriers against severe accidental harm through the phases of a project's life cycle based on the methods and tools of the barrier indicator.

A previously published report in Norwegian describes the work with development and testing of the method: https://sfsba.no/wp-content/uploads/2020/03/Rapport-Barriereindikator-feb.-2020_endelig-1.pdf

The development of the barrier indicator has taken place in the project «Leading safety performance indicators in the construction industry». The aim of the project is to develop performance indicators for managing safety at construction sites that are complementary to the lagging safety performance indicators in use today. ProsjektNorge and RVO-fondet financed the project in the period 2016-19. In 2020 and 2021, the research has been included in the project «Further testing and digitization of predictive safety performance indicators», funded by Project Norway's BAE program. More information in Norwegian about the project can be found here: https://www.prosjektnorge.no/forskning/aktive-prosjenester/utvikling-av-proaktive-indikatser-i-ba-bransjen/

The guide aims at HSE and OHS advisers, quality engineers, safety representatives in contractor and client organizations, and regional safety representatives. The guide also aims at managers and technical expertise involved in the establishment and use of the barrier indicator and follow-up of results.

The content of the guide

The guide combines a description of the use of the barrier indicator with a description of the underlying theory. The latter gives the user a basic understanding of how the barrier indicator works. The theory also explains why the indicator, when used correctly, can be expected to make a significant contribution to the prevention of severe harm to people.

There is a clear separation between practice and theory in the guide. After an introduction in Chapter 1 including purpose of the guide, limitations to the barrier indicator and background, Chapter 2 provides an overview of the steps in the use of the barrier indicator. The purpose is to provide the reader with the necessary practical understanding, to which the content of the following two theoretical chapters can be related.

Chapter 3 takes the reader through the basic principles of quality management and the use of indicators as a management tool to control performance within critical area of production. Quality management provides core principles for the management of safety, which is also reflected in the standard ISO 45001, «Occupational Health and Safety Management» (ISO 2018).

Chapter 4 presents the theoretical basis for the design of the barrier indicator. The chapter begins with accident and barrier theory. The reader is given a description of nine different types of barrier functions and how they intervene into the event sequence during an accidental event. An important section for the use of the barrier indicator describes limitations to barriers. Then follows a description of the structure of the checklists, which represent a central part of the indicator. The chapter concludes by combining the principles of quality management in Chapter 3 with accident and barrier theory to explain how the barrier indicator provides a basis for the measurement and management of safety performance.

Chapter 5 details and expands the description in Chapter 2 of the steps in the use of the barrier indicator. The chapter takes the reader through the entire process from the decision to use the barrier indicator, planning and preparation, the actual inspection of safety-critical activities, assessment and compilation of the result and follow-up and close-out of the findings. Chapter 6 gives the reader a brief account of other uses of the methods and tools that make up the barrier indicator. Finally, Chapter 7 outlines an approach to the management of barriers through the phases of a project's life cycle.

The seven checklists that have been developed are shown in the Appendix. It also contains an example of the documentation of an inspection activity and details about the basis for the checklists.

Thanks

Several organizations and individuals have made significant contributions to the various phases in the development of the barrier indicator. The author would like to thank senior adviser Stig Winge in the Norwegian Directorate of Labour Inspection Authority for help with statistics on fatal accidents in construction in Norway in 2011 - 2016 and for valuable discussions on the interpretation of the results of statistical analyses. Thanks also to construction managers and workers at Skanska Trondheim and to regional safety representatives in the construction industry for important contributions with professional experience in the development of the first version of the checklists.

The Norwegian Public Roads Administration has played a key role in the further development and testing work. The author would especially like to thank chief engineer Jan Erik Lien and senior engineer Bjørn Wang for their decisive efforts in establishing this collaboration. The author would also like to thank OHS advisor Arvid Løver and project manager Tom Hedalen of project E134 Damåsen-Saggrenda and construction managers and OHS advisors in the project for important contributions in further developing the checklists and anchoring them in extensive experience from construction activities.

Thanks to Statsbygg for the opportunity to test the method in an initial phase in the projects New National Museum and Campus Ås. The main part of the work with testing and further development of the method has taken place under the auspices of the Norwegian Public Roads

Administration and Skanska in the rehabilitation projects at the Ekeberg, Svartdal, and Festning tunnels and by the Norwegian Public Roads Administration with AF as the main contractor in the Vålereng tunnel. The author owes a special thanks to OHS advisor Henning Iversen, who has taken the lead for a large part of the testing work in the two rehabilitation projects. Henning has also been a key discussion partner in combining HSE and quality assurance subjects in the further development of the procedures and checklists for the barrier indicator.

Finally, Jan Arild Berget, Norsk Hydro, Jan Hovden, NTNU, Jan Erik Lien, SVV and Geir Kåre Wollum, RVO, are thanked for their contribution to quality assurance of the Norwegian version of this report.

Contents

1 Introduction

1.1 Purpose

The purpose of this guide is to convey how to establish and use the «barrier indicator» as a method in the quality and safety work in the construction industry.

The barrier indicator measures the availability of barriers in safety-critical construction activities. Such activities involve the management of large amounts of energy with a potential to cause fatality or permanent disability of personnel. The aim of applying the barrier indicator is to ensure that the necessary barriers are in place to eliminate or reduce such consequences in case of inadequate control of the activity.

The guide includes checklists to prevent a selection of "typical" accidents that dominated the statistics from the Norwegian Labour Inspection Authority on fatal accidents in construction for the years 2011 - 2016. These accidents are characterized by specific combinations of the type of activity and type of hazard involved. It also includes guidelines on how to develop similar checklists for other types of accidents with the potential for severe harm.

The guide addresses how the results from the measurements can be used to correct individual barriers and to monitor and improve the overall performance in the protection against severe harm. The intention is to provide results in 'real time' and in that way to give the companies involved on construction sites a means of achieving effective safety management.

The guide is aimed at typical user groups for the barrier indicator, primarily HSE and OHS advisors, quality engineers and safety representatives in contractor and client organizations. The guide is also aimed at site managers and technical expertise, who will be involved decisions concerning the establishment and use of the barrier indicator and follow-up of results.

The barrier indicator has been developed primarily to check the condition of safety barriers and use the result to quantify the availability of such barriers. The method consists of two tools:

- A collection of checklists for use in inspections of the condition of barriers on construction sites and
- A procedure for planning and carrying out control activities and for follow-up, including calculation of the barrier index based on the result.

The checklists are developed using a method for barrier analysis. The checklists and the underlying method also have other uses:

- Basis for the planning of routine safety inspections of barriers at the construction sites.
- Investigation of barrier failure in the event of serious accident.
- Follow-up of risk analyses during the planning and engineering phase with specific measures to reduce risk.
- Follow-up of risk analyses during the planning of safety-critical activities in production.
- Control of the availability and quality of barriers in safety-critical activities before start-up of work.
- Planning of HSE audits.
- Systematic management of barriers through a construction project's life cycle.

1.2 Limitations in the use of the barrier indicator

The barrier indicator represents an approach in the area between routine safety inspections and audits. This means that the users of the barrier indicator need to have management and system competence and an analytical disposition in addition to competence on regulatory requirements for building and construction sites. It is an advantage if the barrier indicator is used by a group of personnel with complementary skills.

The barrier indicator can be used by companies as part of their internal control of own construction activities. It can also be used by construction clients or main contractors to check that contractors and subcontractors perform work in accordance with the contract. The use depends on a good interaction between the client, contractor, and subcontractors in that the various parties accept and understand that principles from quality management are applied to safety.

The use of the barrier indicator is more time-consuming than a traditional safety inspection. It focuses on safety-critical activities at the construction site and checks that the preconditions for a safe and successful execution are satisfied. The checking includes the quality of the people executing the work, machinery, tools, and method of work and instructions. Observations and interviews in the field can often be finished in approx. half an hour. The "paperwork" to check formal competence, technical documentation, instructions, risk analyses etc. often take more time, depending on how accessible the documentation is. Time use shall be weighed against the opportunity to uncover safety-critical conditions that are not normally identified in traditional inspections. This will provide possibilities for achieving lasting improvements in safety in the workplace.

2 How to measure safety performance using the barrier indicator?

The barrier indicator is based on the theory that an accident resulting in harm to people starts from normal production and goes through three phases starting with lack-of-control, followed by loss-of-control and finally development of harm. Barriers are not needed in normal production but are designed to intervene in any of the phases to avoid or reduce damage to human life and health. This theory is presented in Chapter 4.

Chapter 5 presents the procedure for using the barrier indicator in production on construction sites. Here is a brief overview in eight steps:

Steps in using the barrier indicator at a construction site:

1. Identify activities to be inspected and in which periods it is relevant to carry out the inspections based on the activity plan for the project. Cover all relevant activities in each period. This should not exceed two weeks to allow for a reasonably timely feedback of the aggregated results of the barrier index for the period. Establish a plan for implementation and document this in the project's control plan.
    a. To get a representative sample, it is recommended to make five or more inspections during each period.
    b. To study developments in the barrier index, it is recommended to carry out inspections for a minimum of three periods.
2. For each activity to be examined, review the current checklist, and focus on points that require checking of documentation. Obtain relevant documents and use them in planning the inspection.

3. Carry out the inspection when relevant activity is carried out. For each activity, check the conditions at the workplace using the checklist on the front of the form and conduct the relevant observations, interviews, and document checks.
4. Review the results of each activity to identify any need for complementary information. This may apply to documents, which are still missing, or the need for further interviews with e.g., supervisors or specialists.
5. Document the results from each inspection in the designated form on the back side of the checklist. This should be done shortly after completing the inspection, preferably on the same day.
   a. For each checkpoint, clarify whether the conditions are satisfactory or not (OK / DEVIATION) or whether the point is NOT RELEVANT. Take photos, if applicable, of checked documents and of findings in the workplace.
   b. For checkpoints, where the conditions are not satisfactory, briefly describe the deviations on the back of the form. Add photos to illustrate observations (Deviations/OK).
6. Compile the results of the inspections for a period into the barrier index. Calculate for each checklist the number of checks that show OK conditions and the number of DEVIATIONS. Checks that are NOT RELEVANT do not count in the calculations. The barrier index (BI) is calculated as % OK of the sum of OK checks and DEVIATIONS:

$$BI\ (\%) = \frac{Number\ of\ OK}{Number\ of\ OK + Dumber\ of\ DEVIATIONS} * 100$$

   This can be calculated as an average for all checks in a period or for each type of checklist in the same period. Figure 2-1 shows an example of presentation of results.
7. Follow up on individual findings in the inspections (DEVIATION) and on the result of the measurement of the barrier index.
8. Repeat the checks regularly in new periods and present the results in a control chart. This can be done until a consistently good result has been achieved. Then the frequency of inspections can be reduced.

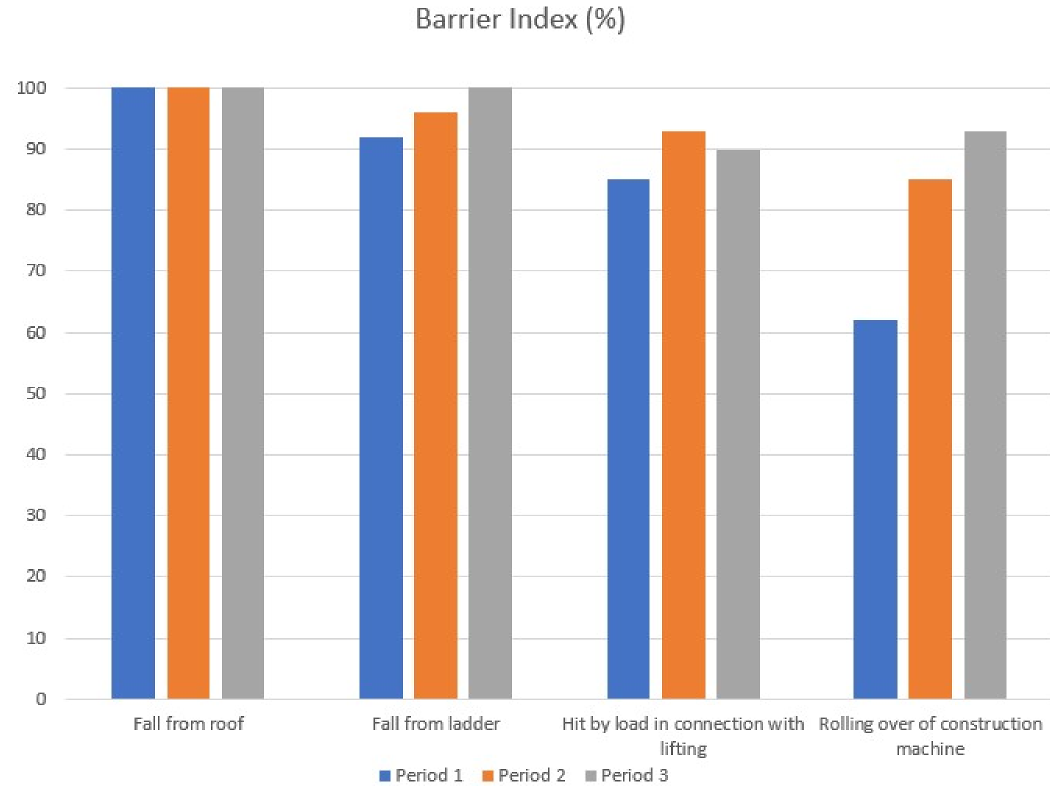

Figure 2-1. Example of how the results may be presented in separate control charts for different types of events.

Example: Appendix in Section 9.2 shows the result of a check of work in a boom lift in connection with the rehabilitation of a tunnel using checklist no. 5, «Squeezed by a crane or a passenger lift in motion». The work consisted of reinforcement in tunnel roofs and leak sealing. At the same time, a check was performed using checklist no. 2, «Fall from machine / equipment», which is not shown.

Checklist no. 5 has 16 checkpoints. Of the points checked, 10 were ok, four represented deviations and two were not relevant. This gives a barrier index for the current activity of:

$$BI\ (\%) = \frac{Number\ of\ OK}{Number\ of\ OK + Number\ of\ DEVIATIONS} * 100 = \frac{10}{10+4} * 100 = 71\%$$

3 Why measure safety performance?

The ISO family of standards for quality and safety management systems specify requirements to monitoring, measurement, analysis, and performance evaluations as central elements of such systems. This is illustrated by the "control and correction" activities in the PDCA wheel, Figure 3-1. The PDCA wheel represents a common framework of the standards in this family. To achieve lasting improvements in performance, system changes must take place.

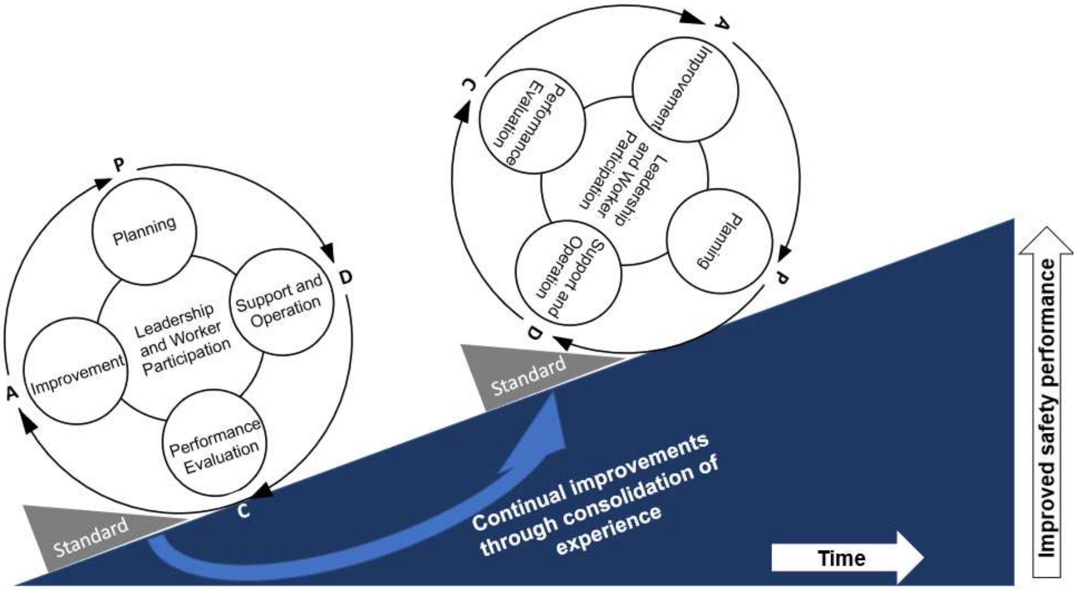

Figure 3-1. The PDCA-wheel is a central framework in the management of quality and safety (cf. ISO 45001).

Guidelines for checking and measuring safety performance can be found in the standard ISO 45001, Occupational health and safety management systems, Chapter 9. The barrier indicator is related to Section 9.1.2 on guidelines for monitoring compliance.

The barrier indicator is a supplement to traditional, loss-based indicators such as the LTI- and TRI-rates in measuring safety performance, Figure 3-2. Loss-based indicators have been in use since the 1920s and they are generally accepted despite serious weaknesses. The popularity of the indicators has to do with the fact that data for the calculation of the LTI- and TRI-rates are, as a rule, registered for other purposes as well, e.g., in registration of working hours and in claim reports to the insurance company. LTI and TRI statistics have also been clear and easy to disseminate. The indicators are often perceived as suitable for safety management by goal setting and for use in qualification of contractors. Experiences show that both these practices may have adverse effects in the form of corrupting the reporting og accidents.

The LTI and TRI rates are examples of lagging indicators based on historical data, item 2 in Figure 3-2. The time it takes for reliable LTI and TRI rates to be established complicates the use such data in the management of safety at construction sites. This has to do with the fact that workplaces are changing at a pace that makes the LTI and TRI rates no longer representative when they are available. The barrier indicator represents a real-time indicator, i.e., results from measurements are available without significant delay (item 1). Indicators based on risk analyses make it possible to manage safety work based on the expectation of future development (item 3).

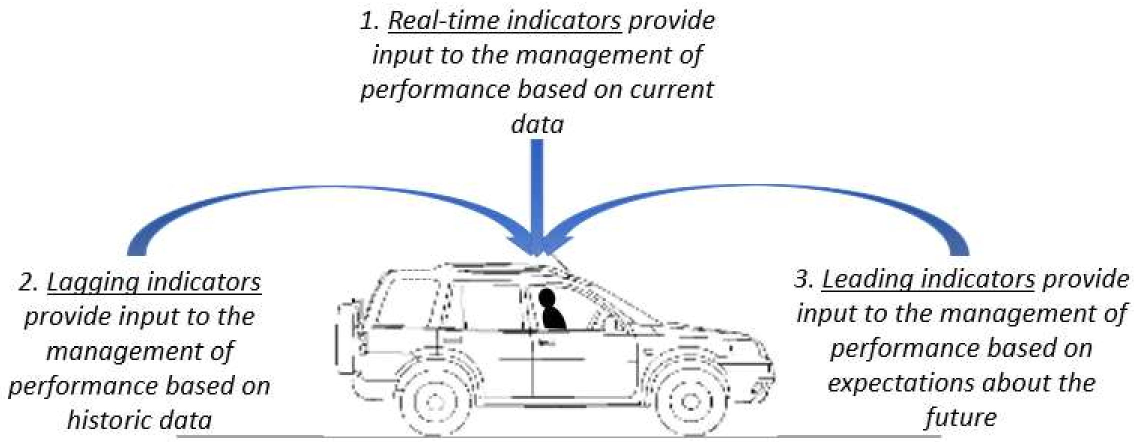

Figure 3-2. The use of indicators in safety management are here illustrated by information gathering in driving. An experienced driver will not only base his/her performance on what is happening in the immediate surroundings of the car but will also "ready" the traffic further away in the direction of the car to avoid surprises. Experience back in time, e.g., about road surface conditions, are also of relevance but may not be representative for the conditions moving forward.

Although the barrier indicator does not replace the use of loss-based indicators, it complements these by being significantly better suited as a method for safety management through compliance monitoring and target setting (Kjellén & Albrechtsen 2017):

- The indicator is valid in the sense that it expresses changes in the risk of accidents with severe consequences on construction sites in a way that is relevant for control. The indicator is well-founded in barrier theory and empirical data from fatal accidents in the construction industry.
- The indicator is sensitive to changes in the availability and quality of barriers and provides feedback without significant delays. Site management and the HSE organization at the construction site have control over the conditions that affect the possibilities for reliable measurements of safety performance and timely correction in the event of a negative development. These conditions include: 1) the frequency and scope of the inspections to check barriers; 2) the qualifications of the inspectors (motivation, competence, and integrity); and 3) how quickly the results are analysed and made available after completed inspections.
- The results are well suited as a basis for decisions on risk-reducing measures. They point to the need to act, i.e., due to a low value on the barrier index or the identification of critical deviations from accepted standard. The results may also be used as a basis for system changes to achieve sustainable improvements.

4 How does the barrier indicator work?

4.1 The accident sequence-of-events

The barrier indicator is based on the principle that most harm in connection with occupational accidents occur when the human body encounters an energy flow, Figure 4-1. This energy has its origin in an energy source (hazard). Harm to the human body occurs when the amount of energy is large enough and hits the body with a sufficient concentration and speed so that the impact exceeds what the body can endure (i.e., the body injury threshold).

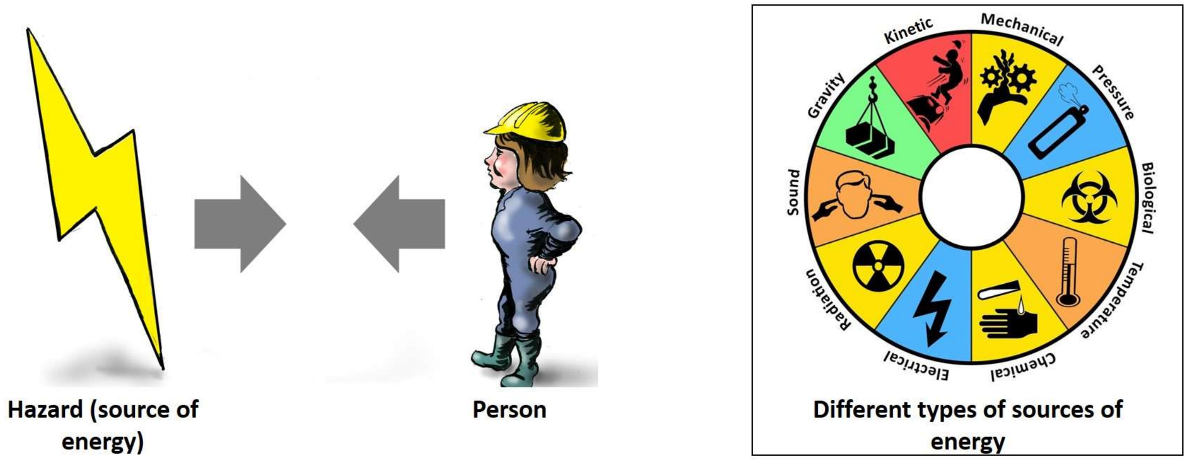

Figure A ***Figure B***

Figure 4-1. Injury occurs when a person encounters an energy flow, which originates in a hazard (Figure A). The pie chart in Figure B shows different types of energy.

The hazard may be in the environment of the person, e.g., suspended loads (gravity), moving vehicles (kinetic) or electrical voltage. It can also constitute the energy that the human body represents when the body's centre of gravity is above the ground level (gravity) or moves (kinetic energy). Muscle energy also represents a hazard. The use of hand tools may accidentally transfer muscle energy to the body with enough force and concentration to harm.

There is a clear link between the amount of energy and the extent of harm. This is illustrated by driving a car. A pedestrian or cyclist has 4 - 5 times greater risk of being killed in a collision with a car at 50 km/h, compared with 30 km/h (Institute of Transport Economics 2017). The car's kinetic energy is about 3 times higher at 50 km/h than at 30 km/h.

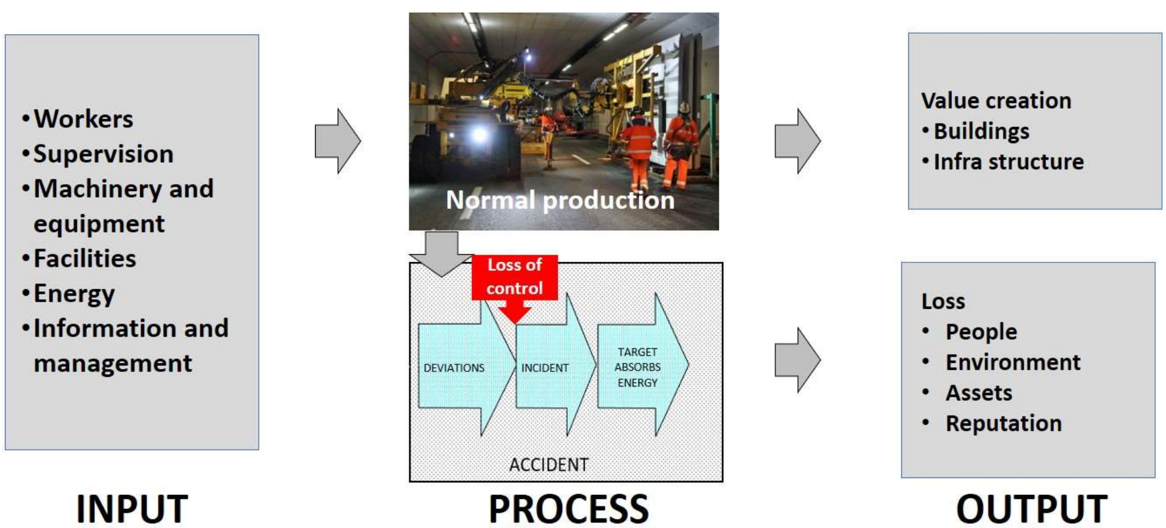

Figure 4-2. Illustration of a normal production process and an accident process in volving lack of control, loss og control and loss. Both processes are dependent on the same resources (input) but have different outcomes (output).

Production is dependent on resources (input) to creates values (output), Figure 4-2. Deviations from what is planned or intended occur also in normal production due to a lack of control. Dependent on the type, frequency and duration of deviations, production becomes increasingly unstable, and loss of control in the production process may occur. The loss of control may in its turn result in loss.

An accident sequence develops through three phases, Figure 4-2. The first phase is characterized by a lack of control, which results in deviations occurring in production. Examples are improvisations by the work force to compensate for inadequate supply of material or tools. Improvisions will often increase the risk of adverse events and harm. Barriers that are not in place or have been used incorrectly are also examples of deviations due to lack of control.

The second phase starts with the loss of control of energy in the system or of human movement in relation to the energy flow. The source of the energy is usually part of normal production. In the third phase, the human body encounters the energy flow and harm occurs.

Loss of control can be illustrated by two examples:

- Example 1: A front loader is located on a slope while filling a ditch with mass and a person stands in the ditch to level out the filling mass. Suddenly, the front loader begins to skid in the direction of the person.
- Example 2: A person works with assembly on an inclined roof. He slips and thereby loses his balance and falls from a height of 5m.

Figure 4-3 presents the result of an analysis of fatal accidents in the Norwegian construction industry in the period 2011 – 2016. The cake diagram shows the distribution of fatalities by type of energy that has been involved. It is clear from the statistics that there are a relatively few types of accidents with a high energy content that dominate the fatality statistics. Dominant types of accidents are falls from a height (gravity), hit by a construction machine (kinetic), tipping over / road departure by a construction machine (gravity), and falling object (gravity).

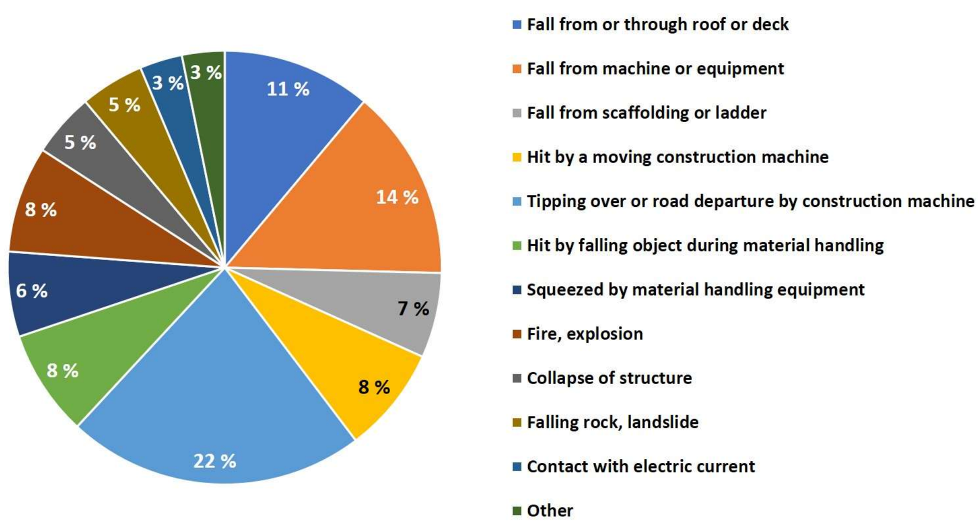

Figure 4-3. Fatalities in building and construction in 2011 - 2016 (N=63, 60 events).

In developing the barrier indicator, this distribution has been a starting point. The use of the barrier indicator emphasizes activities, which involve handling energies with a high potential for damage. The version of the barrier indicator presented in this guide includes the following combinations of activities and energies:

- Checklist 1 - 3: Work at height, i.e., fall from roof or deck, machine or equipment, or ladder.
- Checklist 4: Person hit by falling load or other falling object in connection with crane lifting.
- Checklist 5: Person squeezed by crane / lift in motion.
- Checklist 6: Person hit by moving construction machine.
- Checklist 7: Operator or passengers injured during tipping over of construction machine or accidental departure from road or work area

4.2 What is a barrier?

The barrier concept used in the barrier indicator is based on nine of Haddon's ten strategies for reducing damage from hazards (Haddon 1980). The tenth involves stabilisation, repair, and rehabilitation of the victim and is thus not included. Haddon's strategies were originally developed to prevent severe motor vehicle accidents but are generally valid in the prevention of harm from any type of hazard. They have been instrumental in the successful work by the road authorities in, e.g., Sweden and Norway to reduce the frequency of road accidents resulting in fatality or permanent disability ("zero vision"). The strategies are also clearly visible in the European Union's directives on, e.g., machinery and chemical safety.

In this guide, a barrier is defined as a set of system elements (human, technical, organisational) that provide a barrier function, Figure 4-4. This function has the purpose of intervening in an accidental sequence of events to eliminate or reduce loss.

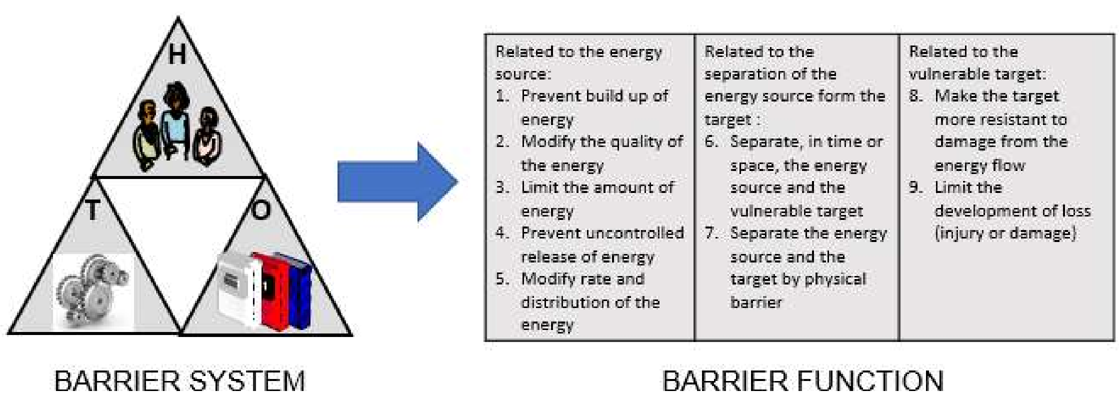

Figure 4-4. A barrier has a function, which intervenes in a sequence of events to avoid or reduce harm. It is realized by a barrier system, which can be a technical protective device or a combination of human, technical and organizational elements (HTO). The first five barrier functions are aimed at affecting the hazard or the initial energy flow, the middle two at separating the person from the hazard, and the last two at reducing harm to the person that meets the energy flow.

A barrier does not fill a purpose in normal production. Its aim is to intervene through its barrier function when production does not proceed as planned to avoid or reduce harm to people, Figure 4-5.

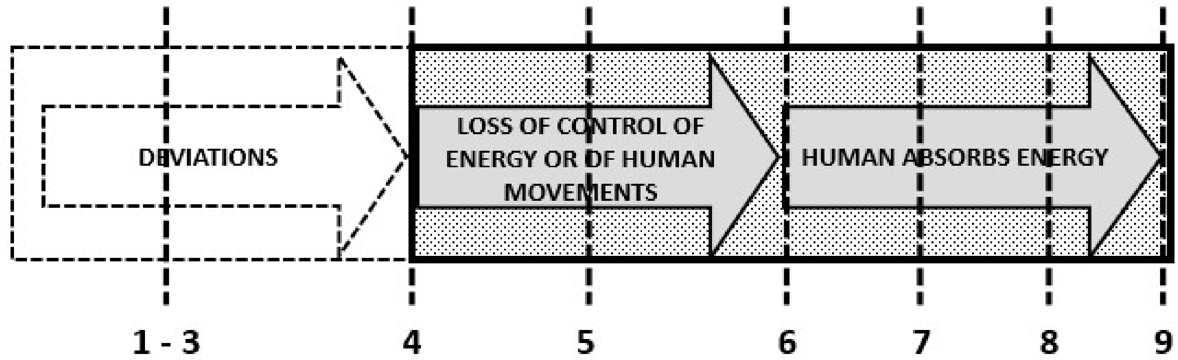

Figure 4-5. Illustration of where in a sequence of events the various barrier functions 1 - 9 intervene to eliminate or reduce losses (Kjellén & Albrechtsen 2017).

Below are some examples of barrier functions, of which some are represented in the seven checklists of this guide:

- Related to the hazard:
    - Avoiding or reducing the scope of work at height (1). This barrier often requires the selection of technical and architectural solutions at an early phase of the project. An example is prefabrication, which will reduce the scope of assembly work above ground level.
    - Use of slurry for blasting that is supplied in non-explosive components. The slurry will only be able to detonate when the components are mixed during supply to the borehole (2).
    - Use of speedbumps to reduce speed when driving on construction roads (3).
    - Use fail-safe coupling during crane lifting to avoid loss of load (4).
    - Apply protection caps to rebars to concentration of energy if a person falls against them (5).
    - Use of seat belt to limit harm to the operator or passengers in accidents involving tipping over of construction machines (5).
- Related to separating the hazard from humans:
    - Avoid movement of people in the danger zone of suspended load during crane lifting or moving construction machinery (6).
    - Use of railing to avoid falling from roof; use of roll-over protection (ROPS) to avoid squeezing in case of tip or roll over of construction machine (7).
- Related to the human:
    - Make people more resilient by using personal protective equipment (8).
    - Limit harm through first aid, evacuation of the injured and transport to hospital for treatment (9).

Figure 4-5 also illustrates that loss can be prevented through the introduction of layers of independent barriers. This way of thinking has especially evident in industries involving the management of large amounts of energy such as the oil and gas and nuclear industries. The construction industry also applies multiple barriers to prevents serious harm. In examples 1 and 2 in Section 4.1, two barriers must fail for the event to result in a loss:

- Example 1: Prevent the front loader from starting to skid (barrier function 4) and prevent the person in the ditch from being in the danger zone of the machine in case of uncontrolled movement (barrier function 6).
- Example 2: Prevent the person from slipping and losing balance (barrier function 4), prevent falls to a lower level by means of railings (barrier function 7), reduce harm by use of personal fall protection (barrier function 3 and 5).

The examples also illustrate that the barriers have different degrees of complexity. A railing is a simple barrier system, which consists of a technical barrier element.

The barrier, which is intended to prevent the front loader from starting to skid, is considerably more complex and consists of elements within all three «HTO areas», human, technology, and organization (cf. Figure 4-4):

- The machine operator must be competent through practical and theoretical training to be adequately aware of the machine's limitations and how to use it. The operator must also be qualified to assess whether the machine is operating adequately or not.
- The machine must be certified and suitable for the work operation. The surface must satisfy requirements to slope, stability, and friction.
- In addition, the necessary operating instructions for the machine and instructions for the job must be available. Machine-specific training must be completed.

We distinguish between passive and active barriers. The barrier function of a passive barrier becomes available when the barrier has been adequately installed. A railing is a passive barrier. Another example is roll-over protection for vehicles.

A barrier that intends to stop the front loader from sliding down the slope following an initial loss of friction is an example of an active barrier. The function of such a barrier is activated by the machine operator or a technical system detecting the initial skid and introducing actions to counter it. Another example of an active barrier is door in a fire wall that is normally open but is automatically closed when a fire is detected by heat or smoke detectors.

As a rule, it is more difficult for an inspector to judge whether an active barrier is adequately available or not, compared with a passive barrier. This is also reflected in the complexity of the checklists, which have been developed for the use of the barrier indicator. We return to this in 4.5.2.

4.3 Barrier limitations

Investigations after severe accidents usually identifies barriers, which are either not in place or have failed. Different types of such limitations are summarised in Figure 4-6. In the use of the barrier indicator, the inspector shall decide: 1) whether the barrier has been put in use in the first place; 2) whether it has been put in use in a correct way and is still operational; and 3) whether human, technical, and organizational preconditions for the barrier function to provide planned performance in an accident are present.

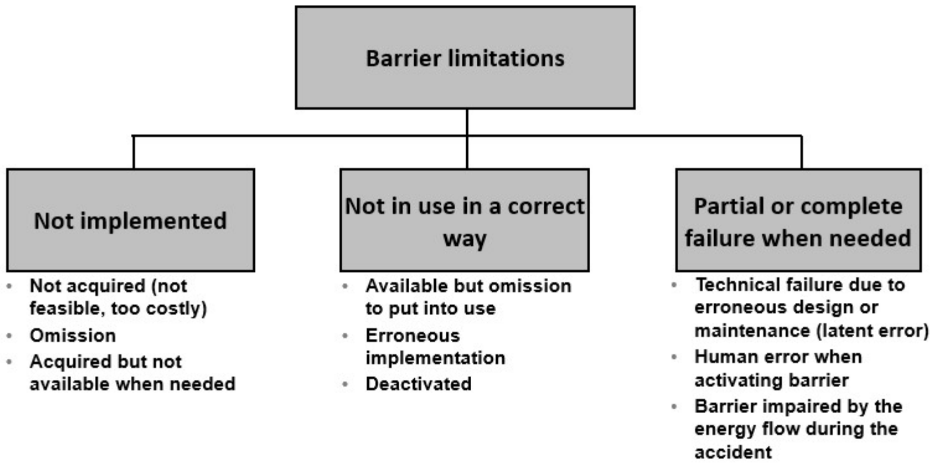

Figure 4-6. Limitations of barriers (adapted from Trost, W.A. and Nurtney, R.J. 1995).

It will usually be relatively easy for the inspector to clarify the first two points. The question of the correct implementation of barriers in point 2 will in some cases require cutting-edge expertise on the relevant barrier type.

The third question, whether the preconditions are present for the barrier to function as intended during an accident, is often more demanding to answer. This applies, i.e., to latent errors, which are "hidden faults" in the barrier due to incorrect design or poor maintenance. An example is an accident caused by an error in the programming of the control system of a machine, which leads to a critical barrier not being activated correctly in an accident. Such defects will not be detected in normal production, where the barrier is inactive. They will also often be difficult to detect in an inspection without a thorough examination.

It can also be demanding to judge whether the personnel have the necessary qualifications to ensure adequate performance of a more complex barrier consisting of human, technical and organisational barrier elements.

The examples in connection with Figure 4-5 illustrate the approach in this guide to make it practically possible to inspect complicated barriers. The inspection includes a review that the involved personnel and technical barrier elements have been subject to quality assurance, and that the results are documented and available as a proof of compliance with the quality requirements.

4.4 Barrier analysis

The checklists of the barrier indicator are based on the results of barrier analyses. The method for barrier analysis was originally developed for use in investigations of serious incidents (Kjellén & Albrechtsen 2017). It is also suitable for use in identifying safety measures based on risk analyses when planning activities with a high potential for injury.

The barrier analysis addresses critical hazards from risk analyses. For each hazard, an analysis is carried out to identify barriers that are of crucial importance to prevent severe injury in case an unplanned event occurs in the relevant work operation. The analysis also includes an identification of possible limitations of each barrier that will prevent it from fulfilling its purpose.

Table 4-1 shows the barrier analysis that formed the basis for the design of checklist no. 7, «Tipping over of construction machine or accidental departure from road or work area». The table does not include the details, but these can be identified in the checklist (Section 9.4). As a starting point for the barrier analysis, data from the Norwegian Labour Inspection Authority on fatal accidents in construction in 2011 - 2016 were used. The data included descriptions of the course of events and information on barrier failures. The results were then supplemented in meetings with professionals from the industry, where experiences from hazards and barriers were discussed in detail, see Section 4.5.1. The work also included a review of the regulations, where the « Regulations concerning the performance of work, use of work equipment and related technical requirements» were central (Norwegian Labour Inspection Authority 2021).

Table 4-1 is valid for the use of construction machinery in general. For a specific work operation in a project, it is possible to make it more specific.

Table 4-1. Form for barrier analysis with example " Tipping over of construction machine or accidental departure from road or work area".

No.	Type of barrier	Of relevance to the current activity and hazard	Limitations of barrier
1	Prevent build-up of energy	Not relevant	-
2	Modify the quality of the energy	Not relevant	-
3	Limit the amount of energy	Not relevant	-
4	Prevent uncontrolled release of energy	Both passive and active barriers to prevent loss of control of the machine. Barrier elements include operator, machine, instructions, and the environment.	Lack of implementation and control of measures adapted to the work operation
5	Modify rate and distribution of the energy	Use of seat belt	Lack of implementation and control of measures adapted to the work operation
6	Separate, in time or space, the energy source and the vulnerable target	Not relevant	-
7	Separate the energy source and the target by physical barrier	Implement guardrails at the edge of the road or work area The machine is equipped with roll-over protection system (ROPS) and seat belt	Lack of routines for securing the edge, including maintenance Lack of implementation
8	Make the target more resistant to damage from the energy flow	Not relevant	-
9	Limit the development of loss (injury or damage)	Use of suitable life jacket that allows escape from the cabin and prevents drowning in case the machine runs into water	Lack of implementation Lack of control that approved equipment is in place and that the operator has the necessary training

4.5 Checklists for assessment of barriers

The checklists for use in assessing the status of barriers are a key tool in the barrier indicator. This section presents how the checklists are structured and filled with contents. The structure of the checklists is based on theory, which is presented in earlier parts of this chapter. Work to fill the checklists with contents is summarized in the following section.

4.5.1 Development of the checklists

To understand how the checklists are built up, it will be appropriate to go through how they were developed. This work has been documented in a previous report (Kjellén 2020). Below follows a step-by-step summary:

1. Analysis of the Norwegian Labour Inspection Authority's statistics on fatal accidents in building and construction in 2011 - 2016, Figure 4-3. This analysis formed the basis for the identification of seven combinations of activities and accident types with high potential for severe harm.
2. For each combination of activity and accident types, a barrier analysis was performed, Appendix 2.
3. Use of the barrier model in Figure 4-4 to identify the barrier elements that must function satisfactorily for the barrier to deliver its intended function. The work to develop the checklists was further based on statistics on fatal accidents, on relevant regulations, and on interviews and collaboration with professionals and managers in construction.
4. A first version of the seven checklists was established. It went through an extensive review in working groups where regional safety representatives and managers and HSE advisors in construction projects participated.
5. Testing in construction projects and modifications and standardization of the checklists in several steps. Appendix 7.3 shows the final versions of the checklists.

4.5.2 Structure of the checklists

Figure 4-7 shows the structure of the checklists. All checklists for the seven event types are structured in the same way and cover checkpoints on eight different topics:

1. Management of safety in the activity, risk assessment
2. Work and safety instructions
3. Training, qualifications of involved personnel
4. Technical documentation of barrier elements
5. Periodic control and maintenance of barrier elements
6. Standard of technical barrier elements
7. Use of barriers
8. Emergency preparedness

Figure 4-7 shows the link between the topics and checkpoints for one of the checklists, checklist no. 7, “Tipping over of construction machine or accidental departure from road or work area».

	Check point	O/T	OK	Dev.	Not relev.	Contr. notified
1	Has the construction site layout and accessibility by road been the subject of a risk assessment covering the risk of tipping over or departure from road or work area by construction machine? Does this consider special conditions, e.g., the quality of temporary (bypass) roads?	O				
2	Have the measures from the risk assessment been implemented?	T				
3	Are there instructions for the machine operator, which cover the selection and use of a suitable machine, risks, and safety measures?	O				
4	Are the operating instructions for the machine available? Is the operator familiar with them?	T				
5	Does the operator have an operator's license for the relevant type of construction machinery and documented machine-specific training?	T				
6	Is the machine certified? Are only interchangeable equipment used together the machine, which fall within the declaration of conformity for the machine?	T				
7	Is it documented that the construction road has been dimensioned for the actual transportation needs in construction?	T				
8	Have documented inspections and testing of the machine and interchangeable equipment been carried out by competent person within the last 12 months?	O				
9	Has the machine been subjected to regular control and maintenance in accordance with the manufacturer's recommendations?	T				
10	Is the machine checked daily before use? Is this documented? If defects are detected, are the necessary measures taken to correct them?	T				
11	Are surfaces used by the machine subject to regular inspection and maintenance? Are the surfaces cleared for snow and litter at an acceptable frequency?	T				
12	Is the machine equipped with wheels/track chains with adequate grip to the surface?	O				
13	Do the surfaces used by the machine have good enough safety characteristics with respect to friction, stability, smoothness, drainage, and grade to ensure controlled movement?	O				
14	Are unstable edge zones on construction roads and work areas used by the machine clearly marked or protected by guardrails where road departures may have severe consequences?	O				
15	Is speed managed by speed limits, speed dumps, or constrictions?	O				
16	Is the dump site equipped with a dump berm or dumping machine to avoid backing over the edge of the dump?	O				
17	Is the machine used within the area of use for which it is certified?	O				
18	Are the instructions for safe use of the machine respected? Are the speed limits complied with?	T				
19	Is a suitable life jacket (e.g., inflatable, manual release) in use when driving in an area with a risk of driving into water? Has the operator received training in the use of this?	T				

Management of safety in the activity, risk assessment
Work-and safety instructions
Training, qualifications of involved personnel
Technical documentation of barrier elements (machinery, equipment etc.)
Periodic control and maintenance of barrier elements (machinery, equipment etc.)
Standard of technical barrier elements
Use of barriers
Emergency preparedness

Figure 4-7. Example of checklist and topics that are addresses. The example shows checklist no. 7, "Tipping over of construction machine or accidental departure from road or work area". "O" (observation) means that it is possible to answer the point based on an individual observation. "T" (triangulation) means that the answer must be based on different and independent information sources.

"O" in the checklist stands for observation. This means that the checkpoint can be clarified by a single observation in the field, provided the inspector(s) have the necessary expertise. Triangulation ("T") will require the use of several different data sources. An example is the question of whether the crane operator has the required machine-specific training. This needs to be clarified by checking the operator's documented training and by interviewing the crane operator and possibly also the person responsible for machine-specific training.

The control of checklist points that require more thorough examination with triangulation will be more extensive and time consuming during the period immediately after introducing the barrier indicator at a site. Eventually it will become clear to the inspectors which checklist points that do not need detailed check every time an inspection is performed. This will be the case when previous inspections show that the company has good systems within the relevant areas.

Table 4-2. Overview for each checklist (CL 1 - 7) of which checkpoints cover each topic.

Theme:	**Checklist (CL) and checkpoints:**						
	CL 1	**CL 2**	**CL 3**	**CL 4**	**CL 5**	**CL 6**	**CL 7**
1. Management of safety in the activity, risk assessment	1	1	1	1 - 3	1	1, 2	1, 2
2. Work and safety instructions	2, 3	2, 3	2	4 - 6	2 - 5	3 - 6	3, 4

Theme:	Checklist (CL) and checkpoints:						
	CL 1	**CL 2**	**CL 3**	**CL 4**	**CL 5**	**CL 6**	**CL 7**
3. Training, qualifications of involved personnel	4	4	3	7 - 9	6 - 8	7 – 9	5
4. Technical documentation of barrier elements	5	5	4	10, 11	9	10	6, 7
5. Periodic control and maintenance of barrier elements	6, 7, 12	6, 7, 12	8	12 - 14	10 - 12	11 - 13	8 - 11
6. Standard of technical barrier elements	8 - 12	8 - 12	5 - 8	15	13	14 - 16	1216
7. Use of barriers	13, 14	13, 14	-	16 – 22	14 - 16	17 - 20	17. 18
8. Emergency preparedness	15, 16	15, 16	-	-	-	-	19

4.6 How to use the result of the inspections?

Findings from the inspections are documented in the form used for the inspections, and the results are used in two ways, cf. Chapter 2.

The first use includes actions to correct identified deviations. The actions involve both immediate measures to correct errors and corrective measures at the system level to prevent recurrence.

Example: In the example in Chapter 2 and Section 9.2, four deviations were identified. Three of four measures in the right column of the form in Section 9.2 involve correction of deviations such as producing requested documents and installing missing squeeze protection. The example also includes one measure at the system level, i.e., the establishment of routines to execute and document daily checks of relevant machinery.

The second use, which is reflected in the name «barrier indicator», is based on the principles for managing a business based on measurement of performance, Figure 4-8. The results of the measurement of performance are summarized in an index. For the barrier indicator, the performance is expressed as a percentage of the checked conditions that were adequate. This is a number between 0 and 100. In the example in Chapter 2, the result was a 71% compliance with the standard for the checked items in a single activity (work in a boom lift).

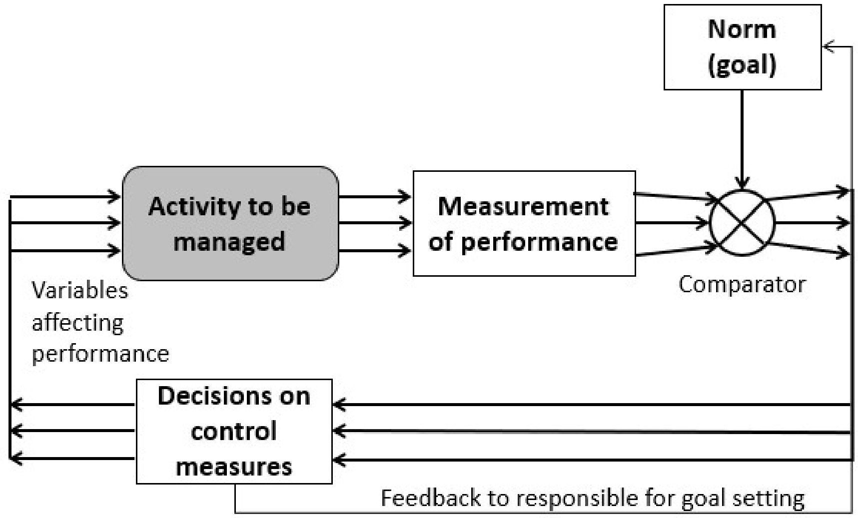

Figure 4-8. Business management based on performance measurement. The model was developed in the 1960s for quality management (Juran 1989) but is also used in safety management, cf. ISO 45001. This figure and the PDCA wheel (Figure 3-1) represent two different ways of illustrating the management of a business based on performance feedback.

The second use includes actions aimed at increasing the value of the barrier index. Let us assume that the management of a construction site has set a goal that the average result for measurements based on the barrier indicator should not be lower than 90%. Follow-up of such an objective will include more comprehensive measures at system level and will aim to achieve lasting improvements. These can, e.g., be directed at the compliance culture in the workplace or the systems for accountability through supervision and control of production. These measures are complementary to the follow-up of each individual deviation. It will be appropriate to base the follow-up at the management and system level on an overall analysis of identified deviations. This will make it possible to search for common characteristics and direct the measures towards them. The earlier example of improvements in intake control for machinery to be used at the site illustrates this type of measure.

The barrier indicator can also be used to monitor developments in compliance over time, corresponding to new rotations of the PDCA wheel. This requires repeated inspections over several periods.

5 Procedure for using the barrier indicator

5.1 Decision to use the barrier indicator

We have previously discussed shortcomings in two safety performance indicators in common use, the LTI and TRI rates. These shortcomings are especially critical when used in the management of safety at construction sites. This is because the two indicators do not provide timely feedback on the safety performance considering the rate of change of work at the site.

The barrier indicator solves this problem by providing feedback on safety performance with minimum delay. The indicator measures the degree of fulfilment of requirements for safety barriers in critical construction activities based on inspections of the activities. The quality and scope of the inspections and the time needed for feedback and decisions are all possible to control by site management.

The barrier indicator belongs to a family of safety performance indicators that are based on a sampling regime for observations of conditions at the workplace. Other members of this family are Safety Sampling, Behaviour Based Safety, and the Finnish TR method used in construction (Kjellén & Albrechtsen 2017; Laitinen et al. 2010). All methods of this family base the observations on theories from statistical quality control.

The barrier indicator also utilises principles for data collection and analysis from quality audits and is hence more labour-intensive than the other methods of the family. This has to do with the fact that several of the checkpoints in the barrier indicator require "triangulation" to achieve satisfactory data quality, i.e., the collection and compilation of information from several different sources before one can conclude. Examples are given in Section 5.3.2. Triangulation provides important information about the quality of critical barrier elements that is normally not checked in a systematic way in traditional inspections.

The barrier indicator has been developed to reduce the risk of accidents with very severe consequences in construction (disability, death). The indicator is thus suitable for use on construction sites, where risk analyses and experience from serious incidents show the need for such an indicator. The use involves quality assurance of construction activities with a high potential for harm to minimise the risk severe injury or death. It is most natural that the initiative comes from the client or main contractor with overall responsibility for the safety of the construction site. The use of the indicator will be adapted to the progress of the work at the site to be prepared when relevant activities are about to start.

The barrier indicator has initially been developed for use in ongoing construction work. During testing of the barrier indicator, it has become evident that there is a need to use the checklists of the barrier indicator in checking that the preconditions for the safe completion of the activity are taken care of at the planning stage, e.g., 2 – 3 weeks before start of work. A third application is to use the barrier indicator immediately before start-up of an activity to confirm that personnel, equipment, and organisation and instructions are ready.

It is relevant in the initial use of the barrier indicator to calculate the barrier index (BI). A low value at a certain point in time (such as BI <60%) or a negative trend will require efforts at the «system level» to achieve sustainable improvement. Systematic checking of critical activities at the planning stage and immediately before starting up will likely reduce the needs of using the barrier indicator during ongoing work.

Chapter 7 addresses the possibilities of widening the scope for application of the barrier indicator and associated methods to include the early project phases. This will allow a more systematic management of barriers throughout the project starting with early planning and design.

Implementation of the barrier indicator will require resources in the form of working hours spent on using the indicator and follow-up of results. There will also be requirements to the quality of these resources. The inspectors must have adequate knowledge and experience to use of methods and to judge inspected safety issues, work practices, machinery etc. The use must also be perceived as expedient by the project management and be accepted by all affected parties on the construction site. The decision to use the barrier indicator will be strategic and included as part of the company's work to achieve a safe and predictable production.

As part of creating trust and legitimacy, information must be provided to affected personnel about the plans for carrying out inspections using the barrier indicator. It is important to emphasize the purpose of the inspections, which is to ensure the quality of work performance and thus prevent serious work accidents. It should be emphasised that this is done by checking the systems in the workplace, not "policing" individual workers.

5.2 Planning and preparation

It is recommended that the client and / or the main contractor implement the barrier indicator in their respective control plan for the project. Scheduling must be based on the project's master plan for construction to schedule the inspection activities in relationship to the relevant construction activities. Detailed planning will then take place in the regular construction meetings (e.g., monthly, weekly).

The detailed scheduling will be dependent on the aim of applying the barrier indicator to safety-critical construction activities:

1. To review the plans for the activity 2 – 3 weeks before starting up. This will include use of the checklists in controlling that the planned use of personnel, machinery and tools, and work and safety instructions are of adequate standard. It will also include a review of the relevant risk assessments and implementation of results.
2. To review the operational and safety readiness of the activity when it is about to start. This use will follow the standard procedure of the barrier indicator.
3. To check compliance in the course of work on a sampling basis. It must be decided whether to carry out these checks more regularly or not. Regular application with minimum five checks per period of 1 – 2 weeks for consecutive periods will allow for the use of a control chart to monitor safety performance over time.

"Spontaneous" checks may also be relevant when using the checklists, e.g., after a serious adverse event. These can provide information on the extent of the problems that the investigation of the event has revealed.

The detailed planning of the use of the barrier indicator in inspecting an activity will include:

1. Identification of the activity and selection of checklists, planning of time for inspection of the activity in the field.
2. Establishment of a group for performing the inspection.
3. Identification by means of relevant checklists of documents, which are to be checked.
4. Acquisition and review of documentation needed to carry out inspections in the field.
5. Planning of field inspection.
6. Planning of documentation and follow-up of the result.

There is no 1 - 1 relationship between activities and checklists (point 1). An example is the use of a personal lift, where both checklists 2 and 5 are relevant. If more than one checklist is used to inspect the same activities, several of the checkpoints, e.g., for machine and personnel, are common and only need to be checked once. The Barrier Index will be calculated based on the actual number of OK's and DEVIATIONS identified.

It is possible for one person to carry out all checks related to the use of the barrier indicator. This person will need to combine methodological knowledge including the ability to carry out «the respectful dialogue» (Section 5.3.1) with knowledge of current work operations and requirements to safety barriers. In cases where the inspections require cutting-edge expertise, e.g., about requirements to fall protection equipment or machinery safety, a single inspector is normally not sufficient. The second inspector can be a technical expert or quality engineer.

The interviews of “foreign language” workers must be planned for. This includes assessing whether the use of a supervisor of the workers as an interpreter is appropriate or not considering the needs of establishing a trustful relationship with the workers.

It is particularly important to obtain and review documentation in advance to the interviews and observations in the field. Examples of this are (cf. Figure 4-7 and Table 4-2):

- JSA / risk analyses of current activities and corresponding OHS plan from the client (Topic 1 in the checklists)
- Relevant work and safety instructions (Topic 2)
- Relevant safety training at the workplace and machine-specific training (Topic 3)
- Documentation of personnel and equipment (Topics 3 and 4)
- Emergency preparedness (plans, implementation through exercises) (Topic 8)

5.3 Inspecting an activity in the field

The inspectors need confirmation from the relevant supervisor that it is safe to approach for an interview. The inspection starts with observation of the activity from a safe position. During a natural break or when it is otherwise safe to interrupt the activity, the inspectors contact the worker(s) to signal their intention. The interview follows a fixed plan:

1. Opening, introducing the inspectors, repetition of previous information about the purpose of the interview (bring out facts to check system, do not "take" person).
2. Start the interview by asking for facts about the person(s) being interviewed (needed for cross-check of information in the employer’s personnel register):
    - Name, position / work assignments, job experience, and when the person in question started in the project.
3. Use the current checklist to ask questions about checkpoints marked «T». The purpose is to obtain information about the person's participation in relevant activities and knowledge of and experiences with these. Use results from previous document review to check that the interviewee has an active relationship to, e.g., relevant courses and JSA. Be careful with time. There is no need for complete statements, only for enough information to confirm or negate active participation.
4. Use the interview to confirm the interviewee’s active relationship to available documentation at the workplace or in the machine (e.g., work instructions, JSA, instructions for use, signs of certification and regular control). Take pictures of documents where needed for further analysis and documentation.
5. Perform a visual inspection of the machine or equipment and clarify any questions with the interviewee (operator). In case of discrepancies, ask how long this has been present and why.
6. Conclude by thanking for the interview.

5.3.1 A respectful dialogue

It is important to achieve a good relationship with the persons being interviewed. This is accomplished by using the principles of a respectful dialogue. It is a conversation in a positive tone between equals about the current work situation, why it is carried out in this way and the preconditions for current choices, Figure 5-1. The interviewer shall treat the person being interviewed with respect. It is important to seek to understand, not to persuade, to listen carefully without judgement, and not to interrupt. Ask open-ended questions such as «what?"," How? "," Why? "," What could have been done better? ". Avoid questions that are leading and / or blame the person being interviewed, such as "Have you?", "Did you?", "Do you want to?".

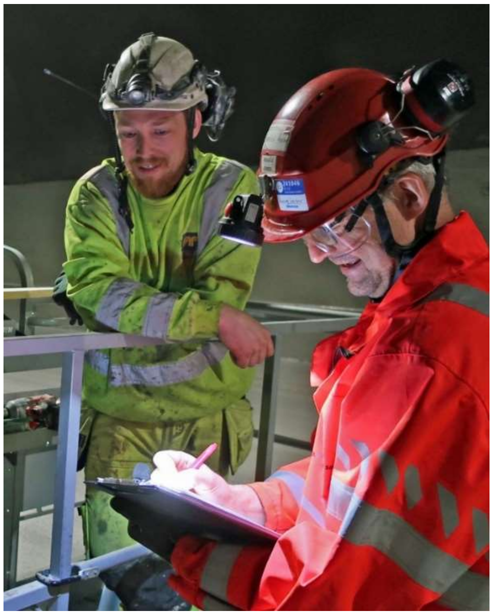

Figure 5-1. Conducting interviews in the workplace must take place according to the principles of the respectful dialogue, i.e., a positive and non-confrontational conversation about the current work situation, about why it is conducted in this way and the preconditions for relevant choices.

The respectful dialogue gives the inspector the opportunity to obtain information about underlying conditions, which in turn can be used to get better solutions at system level to prevent the recurrence of deviations.

Example: The usefulness of the respectful dialogue can be illustrated with an example from electrical installation work. Normally, a personal lift is used for this type of work. When it is too narrow for the lift, the contract requires the use of a platform ladder, Figure 5-2 A. Step ladders are only permitted for use if approved as a nonconformity.

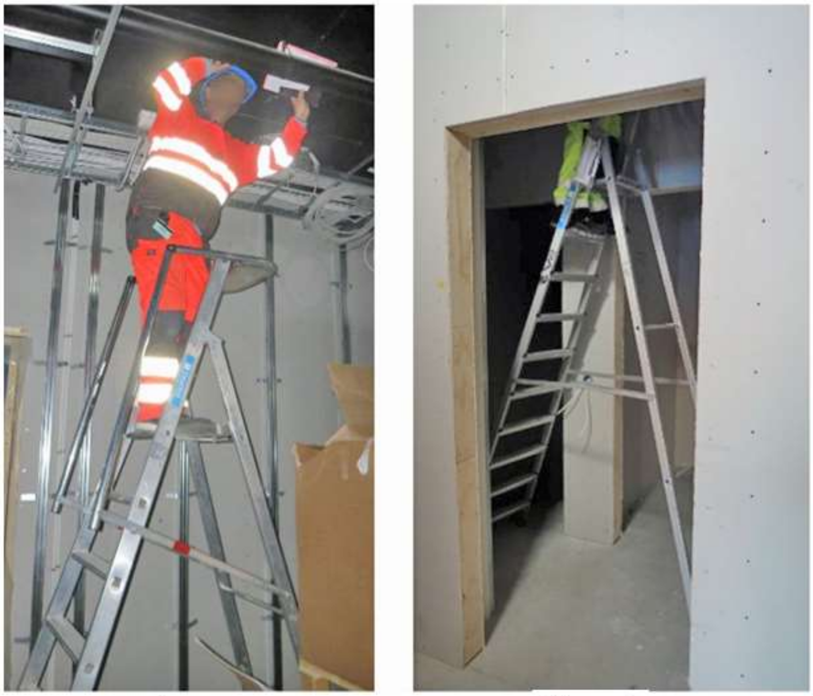

Figure A **Figure B**

Figure 5-2. Execution of electrical installation work from ladder. Figure A shows the use of a platform ladder and Figure B the use of a step ladder.

In an inspection of work at height based on Checklist no. 3, the use of a step ladder during work in a technical room was identified (Figure B). This use had not been subject to nonconformity handling by the employer. The observation was registered as a deviation in the checklist. The inspector followed this up in a dialogue with the worker. He asked why the step ladder had been selected and how the decision was made. It turned out that it was not possible to use a personal lift in narrow technical rooms, and that the working height could not be adjusted when using a platform ladder. The need to use a step ladder had not been addressed by the supervisor, but the worker felt that he was expected to find a solution. He resolved it by borrowing a step ladder from another work team.

The alternative to this dialogue was to register the deviation as a rule violation on behalf of the worker and to apply disciplinary measures. This would jeopardise the use of the barrier indicator as an improvement tool in safety work. In using the barrier indicator, emphasis needs to be put on improvements in the workplace by preventing deviations from recurring. In this example, page 2 of the checklist should be used to comment on the needs of reviewing the planning of installation work in narrow technical rooms. The purpose will be to ensure that satisfactory measures are identified in the instructions and JSA and that the necessary equipment and permits are present when work begins.

Such an approach shifts the perspective from rule violations by the workers to errors in the employer's system for planning and facilitating safety-critical work. Disciplinary measures will still be needed in some cases (e.g., in case of gross negligence), but these should be kept out of the use of the barrier indicator as far as possible.

The example also illustrates the need to follow-up on results through investigations at «higher system levels». In the present case, this applies to the employer's planning of work, the main contractor's follow-up of subcontractors, and in the client's identification of hazards and implementation in the OHS plan for follow-up during construction. These investigations are not part of the method for the barrier indicator.

The respectful dialogue may be challenging to implement in practice. Language difficulties can present major obstacles, as can differences in "culture". Respectful dialogues and follow-up of the result can be perceived as time-consuming and difficult to prioritize in a hectic working day.

To remedy such obstacles, it is important that the premises for the use of the barrier indicator are clarified in advance, see Section 5.1. Sufficient time must be set aside for a professional implementation in consideration of the long-term benefits of the use of the barrier indicator. At least one of the persons in the inspector group must have the ability to carry out the "respectful dialogue" and use the result in triangulation.

5.3.2 Triangulation

The concept of triangulation was introduced in Section 4.5.2. We will here illustrate by examples how it is applied in practice.

A typical example is the need to clarify whether a machine operator has machine-specific training. A "yes" from the operator is not sufficient. The answer must be supplemented with more details from the operator about the training. This information is checked against other, independent sources so that the inspectors can conclude. Ideally, a clarification of this question will require the following information:

- An interview with the machine operator, who confirms (or refutes) that he / she has undergone relevant training. Here it is important that a "yes" is qualified by details about the training, when, where, scope (theory / practice, number of hours) and examples of content. It is enough to get a picture, which confirms / contradicts that the person in question has participated.
- Documentation of the employer's machine-specific training, i.e., content and participants. If the operator does not speak the local language, it should be clarified that the training is given in a language that the operator understands and that documentation (e.g., instructions for use) is available in that language.
- Check that the person responsible for the training has the necessary qualifications. It is also an advantage if this person responsible is interviewed to give an account of the training.

In the initial use of the barrier indicator at a construction site, there will be frequent needs of triangulations to confirm the adequacy of the contractors' management systems in various areas. If it is confirmed that a contractor has a good system, further checking can be reduced or ceased, depending on how robust the system is.

Another example is checking that expert inspection and testing of lifting equipment have been carried out at regular intervals. A prerequisite for this control is that each piece of lifting equipment can be identified individually by tagging. The contractor shall maintain documentation of lists of equipment and dates for inspections and tests by authorised body. The triangulation will include both the "map" and "terrain". The former involves checking that the responsible company has a documented system for periodic inspections and tests, and that it is of an adequate standard. Checking the "terrain" involves inspections of lifting equipment in use at the construction site. It needs to be confirmed that it is tagged, is of an adequate technical and safety standard, and that it is documented in the company's system for regular inspections and tests.

The checklists do not provide detailed advice on how the triangulation shall be performed. This may be developed in a community of practice, where inspectors collaborate to develop a common professional understanding of how the various checkpoints should be used.

5.4 Review and compilation of results

The results from interviews, observations and document reviews are summarised on the back side of the form with checklists used in data collection, see Appendix (Section 9.2). The description of deviations could be supplemented with relevant pictures of the work situation, details of barrier elements, and examples of documentation. The pictures could also include a demonstration of conditions that have been OK.

Checkpoints not being resolved due to missing documentation are classified as deviations with an action on behalf of the responsible company (or main contractor) to produce such documentation to the inspectors. The barrier index is calculated based on available documentation and is updated when additional documentation is at hand.

The inspector must in some cases make a judgement to be able to conclude. In the following sections, some experiences are shared on how to handle cases where a univocal conclusion is not immediately at hand.

5.4.1 Safety management of an activity, use of risk analysis

A recurrent issue in the assessment of the safety management of an activity is whether there are requirements for JSA and whether the JSA is good enough. This question must be seen in connection with the type of work and the work instructions. A JSA is not necessary if the activity being inspected is standardized and covered by a work instruction, and the conditions for which the instruction applies are valid. These conditions include the selection of equipment, the composition of the work group, simultaneous activities in the vicinity of the place of work, conditions in the environment etc.

The JSA shall focus on special circumstances in the execution of the activity in question. The inspectors should consider whether the JSA bears the mark of "copy-paste" from pervious JSA. It represents a deviation, if the observations in the field identify critical conditions that are specific to the current activity but are not covered by the JSA. It should also be checked that relevant hazards in the client's OHS plan and the contractor's risk assessments for the activity are covered by the JSA or work instructions.

There is also a need to check that the measures in JSA and other relevant risk assessments for the work have been implemented. Measures to be implemented by the workers involved in the activity should be verified by checking that the workers know the JSA and their responsibilities in implementing it.

5.4.2 Work and safety instructions

Other frequent observations in using the barrier indicator are missing work and safety instructions and workers lacking an active relationship to them. The responsible employer often argues that the JSA covers the need for work instructions. This is not adequate since the regulations require written instructions for work that entail a particular danger to life and health, see the Norwegian Regulations Concerning Organisation, Management and Employee

Participation §11-1.2 and the Working Environment Act §3-2 (Norwegian Labour Inspection Authority 2020b; Ministry of Labour and Social affairs 2020).

5.4.3 Training and qualifications of involved personnel

Within this topic, missing documentation is also a recurring observation. If the regulations require specific training (e.g., machine-specific training of machine operators), this must be documented, and the individual operator's participation must be traceable.

It is common for the main contractor to organize safety induction training for the personnel before starting to work at the construction site. This usually covers several topics, including work at height (checklist 1 - 3) and risk of staying in the danger zone for cranes and construction machinery (checklist 4 - 6). This training satisfies the requirements of relevant checkpoints in the checklists as far as it can be documented that the involved personnel have participated in the training. It is also necessary that the training has been given in a language the individual worker understands and that the interviewed personnel can demonstrate their active participation.

The use of the barrier indicator involves checking of the qualifications of foreign personnel who have received certified training in their home country. The Norwegian Labour Inspection Authority has an approval scheme for such certificates of competence. It must be possible to present this approval by the authority to the inspectors together with the original certificate of competence for the relevant checkpoints to be considered OK. Machine-specific training must also be documented for the Norwegian Labour Inspection Authority's approval of the competence of the machine operator to be valid.

5.4.4 Documentation of technical barrier elements

Within this area, there are two issues that are particularly demanding to assess.

According to the Machinery Regulations and the Regulations for the performance of work, construction machines must be "EU-approved", i.e., having a Declaration of Conformity and being CE-marked. This also applies to special equipment used with the machine in an "assembly of machinery". An example is an excavator that uses specialised equipment such as buckets and breakers, and a quick coupler to attach the equipment to the excavator. The excavator and the equipment may come from different manufacturers. In this case, it must be checked that the required declaration of conformity is available for the different combinations of machinery and equipment in use. The manufacturer of the specialised equipment is responsible for the assembly and that it meets the requirements. There are unfortunately examples of the use of combinations of machinery and equipment that do not meet this requirement and that the mismatch has resulted in severe harm.

Another issue is the requirement for operating instructions for machinery. The instructions need to be available in a language that the operator understands and shall as a rule be stored in the machine. This will make it easy for the inspectors to check this. The operating instructions must also include the special equipment for the machine that are in use at the time of the inspection.

The inspectors need to judge whether it is sufficient that the operating instructions are only available in the local language at the site when the machine operator does not master that language. The judgement will involve considerations of whether the machine-specific training is good enough to compensates for the fact that the operating instructions are not available in a language mastered by the operator.

5.4.5 Regular control and maintenance of technical barrier elements

Control of checkpoints within this area requires triangulation, cf. Section 5.3.2. Machinery and equipment, for which regular inspection and testing are required, need to be possible to identify, e.g., by a unique identification number ("tag"). Examples are lifting equipment such as fibre straps and shackles.

5.4.6 The quality of technical barrier elements

These checkpoints involve visual inspection, sometimes requiring specialist competence. If such competence is lacking, a not entirely ideal approach is to discuss with the operator whether the equipment satisfy relevant requirements. The results need to be verified after the inspection.

If the inspectors identify deviations, it is relevant to ask the operator about his or her assessment of the deviations and why they are present.

For lifting equipment, it may also be relevant to inspect storage space. The aim is to check that the equipment is stored in a safe and well organised manner that does not impair quality and facilitates the correct use of the equipment.

5.4.7 Use of barriers

These checkpoints deal with whether and how barriers under operational control are implemented and used by the workers or supervisors. Figure 4-6 will here serve as a reminder of what barrier limitations to look for. Examples are checking the use of personal fall protection and the prevention of access to the danger zone when lifting. To be able to assess relevant checkpoints, observation of the work is required, in some cases during a whole work sequence. The observations should also be supplemented with interviews with the workers.

5.4.8 Emergency preparedness

The emergency preparedness checkpoints are aimed at the organization's ability to handle special emergency situations of relevance to the topics covered by the checklists. This applies to the rescue of personnel at height (checklists 1 and 2), and the rescue of an operator, who ends up in water after road departure or tipping over (checklist 7). The checking includes proper establishment of resources (trained people, adequate plans, and equipment) and proper maintenance through regular exercises.

5.5 Calculation of the barrier index

Section 5.5 gives a description of the method for calculation of the barrier index (BI). The calculation can be made as an average of completed inspections for a single period. This period should not exceed two weeks and there should be a minimum of five inspections of activities in a period. The period needs to include a representative sample of inspections covering relevant checklists. This will provide a "snapshot" of the degree of control over barriers in the workplace.

If it is desirable to follow the development over time, the inspections must be repeated for several periods of 1 – 2 weeks.

The calculation of the BI is normally made for all inspections for each period and represents an average. It may also be relevant to calculate the barrier index for a specific topic such as working at height (checklists 1 and 2), crane handling (checklists 4 and 5) or use of construction machinery (checklists 6 and 7). This approach will simplify the analysis of results and follow up with relevant actions at both in the activity and system levels.

In the formula for calculation of the BI, all checkpoints are given equal weight. It is also possible to further develop the method by giving the checkpoints varying weights from 0 to 1, based on professional assessments. This will change both the numerator and the denominator in the formula in Chapter 2. Checkpoints, which are given low weight, should be considered for deletion from the checklist.

5.6 Follow-up of results

It is recommended to use existing systems for nonconformity management in the follow up of identified deviations. It should be agreed between the parties (e.g., client - main contractor or main contractor - subcontractors) which system or systems to use, and what expectations one has for the follow-up and close out.

In the testing of the barrier indicator, two different systems have been used for nonconformity management, for HSE and product quality nonconformities, respectively. It is important to choose a system, which is well structured with a clear and appropriate division of responsibilities between the involved parties. To maintain motivation among the users, the system needs to deliver systematic, effective, and timely follow-up and close out.

The deviations will be of different types and will require varying efforts for follow-up and close out. This can be illustrated by three examples:

- Technical deviations, e.g., faults on railings or lack of automatic squeezing stop on passenger lifts. In managing isolated cases of deviations, it may be sufficient to close the case by correcting the deviation. If the deviations are critical or recurring, they need to be treated as symptoms of «system failures» that require measures aimed at the management level such as contractor's planning and control function (cf. the PDCA wheel in Chapter 3).
- Lack of documentation, e.g., of training / qualifications of personnel, certification or regular control and maintenance of equipment. The immediate measure is to require the responsible employer to produce the necessary documentation. In cases with repeated failures to produce this documentation, measures need to be implemented to ensure that required documentation is available as a prerequisite for the start-up of critical activities.
- The example in Section 5.3.1 with the use of a step ladder for installation work in congested space illustrates a deviation, which may require more extensive investigation. A simple solution is to approve the use of step ladders in this type of work as an approved nonconformity. Alternatively, the involved parties may allocate time to arrive at a more sophisticated solution, for example, rescheduling the installation of separation walls that prevent the use of a personal lift for the installation work. It will be more time-consuming to find such a solution, but the solution will have both safety and production advantages.

The use of the barrier indicator may reveal serious recurring problems in the safety management of safety-critical construction activities. This can, e.g., apply to a lack of integration of relevant information from client's OHS plan in the contractor's risk register and subsequently in the planning of these activities. System audits are a more appropriate method of going into depth on the causes of such system failures.

It may also be relevant to perform in-depth statistical analyse of the accumulated results from the application of the barrier indicator. Such analyses will provide results of use in focusing preventive efforts on measures with the most significant risk-reducing effect.

The follow-up of results from the application of the barrier indicator may involve both sanctions and rewards at the organisational level. Failure to address critical deviations on behalf of a contractor or subcontractor may trigger fines or stopping of work as relevant according to the contract. The barrier index can also be used in an incentive scheme. Bonuses can, for example, be used to reward contractors that are able to start safety-critical activities on time and with a satisfactory safety standard.

6 Other uses

This section provides a brief description of alternative uses of the methods and tools that make up the barrier indicator, cf. Section 1.1. Examples of uses discussed here are listed in the third column of Table 6-1. This column also includes applications relevant to the management of barriers through the life cycle of construction project described in Chapter 7.

Table 6-1. Overview of methods and tools in the development and use of the barrier indicator, applications as part of the barrier indicator, and other relevant applications.

Methods and tools	**Application as part of the barrier indicator**	**Other relevant applications**
Barrier analysis including checklist of barrier limitations (Figure 4-6)	Development of new checklists for other types of accidents with high potential than those covered by existing checklists	In-depth investigations of accidents and critical near accidents Design of measures in the planning and design phase based on risk analyses by the engineer Design of measures to mitigate risks during planning of critical construction activities in the execution phase
Checklists for typical activities and incidents with a high potential for loss (checklist no. 1 - 7)	Control of the availability of barriers in safety-critical activities: - At the planning stage 2 – 3 weeks before start-up incl. intake control of personnel and equipment - Immediately before the start-up of a critical activity - During execution of critical activities in production to get a snapshot of compliance - Control for several periods to study development of compliance over time	Investigation of barrier failure in accidents and near accidents within the checklists' themes Basis for simplified checklists for use in HSE inspections (focus on O in the checklists) Planning and implementation of HSE audits
Calculation of barrier index	Determining the degree of compliance with requirements to barriers is relevant for the different uses of checklists at start-up and in production	Not relevant

6.1 Basis for inspections

A company that uses a system for thematic safety inspections with a rolling schedule may find it valid to use checklists of this guide as a basis for planning of these inspections. Checkpoints that require observation (O) may be used directly, but checkpoints requiring triangulation (T) will normally be outside the scope of an ordinary inspection. A feasible solution is to select a suitable component in such a triangulation, for example that the machine operator can show a valid operator's license for the relevant types of construction equipment.

6.2 Investigation of accidents and near accidents with a high potential for harm

The barrier indicator has been developed to prevent accidents with severe consequences. If an accident or near accident occurs in a workplace, it will be crucial to make an analysis of the extent and causes of barrier failures in this event. For events that fall within any of the seven categories of critical accident types covered by the checklists in this guide, the relevant checklist will be of significant help in the investigation itself.

Barrier analysis was originally developed for use in accident and near accident investigations. In this application, the analysis will primarily focus on the circumstances around the actual event. The columns of the form used in the analysis and documentation of results will differ somewhat from the application in connection with risk analyses in this guide:

- Type of barrier (1st column): Same as for risk analyses, i.e., listing of the nine barrier functions
- Relevance to the hazard involved (2nd column): Same as for risk analyses. The text will be more concrete and describe required barriers and barriers that need to be considered in the future.
- Status of the barrier (3rd column): This differs from the application in connection with risk analyses in that the actual circumstances in connection with the accident are addressed. The column includes and overall assessment (worked as intended/not implemented/not correctly used/failed during the accident) and a factual description of the actual conditions during the accident as revealed by the investigation.

6.3 Risk analyses of activities

In the planning and design phase of a construction project, the client has a duty to ensure that the risk of serious accidents related to own decisions is adequately managed (Norwegian Labour Inspection Authority 2020a). These decisions involve site selection, planning, and architectural, technical, and organizational choices. Where feasible, the identified risks are closed through adequate measures in planning and design. Remaining risks are brought forward together with outlines of risk reducing measures in the OHS plan for construction. The barrier analysis supported by relevant checklists can be used to develop concrete and project-specific measures in planning and design.

The checklists may also be used in production in risk analyses at the planning stage of safety-critical activities. It will also be relevant to apply the checklists in JSAs, when these are executed with the work crew immediately before start-up of safety-critical activities.

6.4 Planning HSE audits

The use of the barrier indicator has in some contexts been called a «mini-audit». Much of the methodology is taken from quality audits (cf. ISO 19011). It does not involve the same strict requirements to the independence of inspectors and to the systematics used in arriving at a conclusion as in an audit. The checklists are well suited for use in traditional system audits on the management of safety-critical activities. The use of the checklists represents a starting point of an audit, and identified deviations need further investigations of management system issues. Similarly, it is recommended to use system audits as a tool in the follow up of critical and / or recurring deviations identified in the use of the barrier indicator.

6.5 Development of checklists for new areas

It is possible to develop new checklists by applying the barrier analysis method on which the existing checklists are based. Examples are checklists for blasting work and for work involving the risk of being hit by falling rock or rockslide. It is recommended to apply the same structure of the new checklists as that used in the existing seven checklists. Users are also free to modify existing checklists, but it is recommended that this does not violate the principles underlying their development.

7 Management of barriers through a construction project's life cycle

This chapter describes a process to the management of barriers through the life cycle of a construction project. The process involves the identification of the necessary barriers for safe execution of critical construction activities at the right time in the project and adequate management in subsequent phases. The aim is to allow for the use of barriers during construction that are efficient in preventing severe harm and robust against manipulation. Its usefulness is illustrated by an example.

Example: A road tunnel was subject to rehabilitation. The work included pigging of old concrete and reinforcement bars in sections of 3 m of the tunnel roof, before the roof was secured by a new reinforced concrete vault, Figure 7-1. During pigging and until the roof was secured, the affected 3 m section of the tunnel represented a danger zone for falling concrete and rock. The client's engineer had identified this hazard during design and the client had included the requirement of restricting access to the danger zone by a physical barrier in the OHS-plan. In inspecting the work during execution, violations of this requirement were identified. It had been left to the machine operator to monitor the danger zone and prevent access during the pigging operation. Further analysis showed that trespassing of the danger zone by construction workers were made to access vehicles at the opening of the tunnel behind the excavator used for pigging. An alternative, readily available and safe access way had not been prepared. This would require an early identification of this limitation of the physical barrier and planning in collaboration between the client and contractor to develop a robust solution.

Figure 7-1. Pigging of concrete vault in tunnel rehabilitation.

Since the interaction between the client and the main contractor is in focus in the barrier management process, the procurement process has been used as a starting point, Figure 7-2. In the figure, the procurement process is seen from the client's perspective, but the same principles will apply for a contractor when subcontracting work.

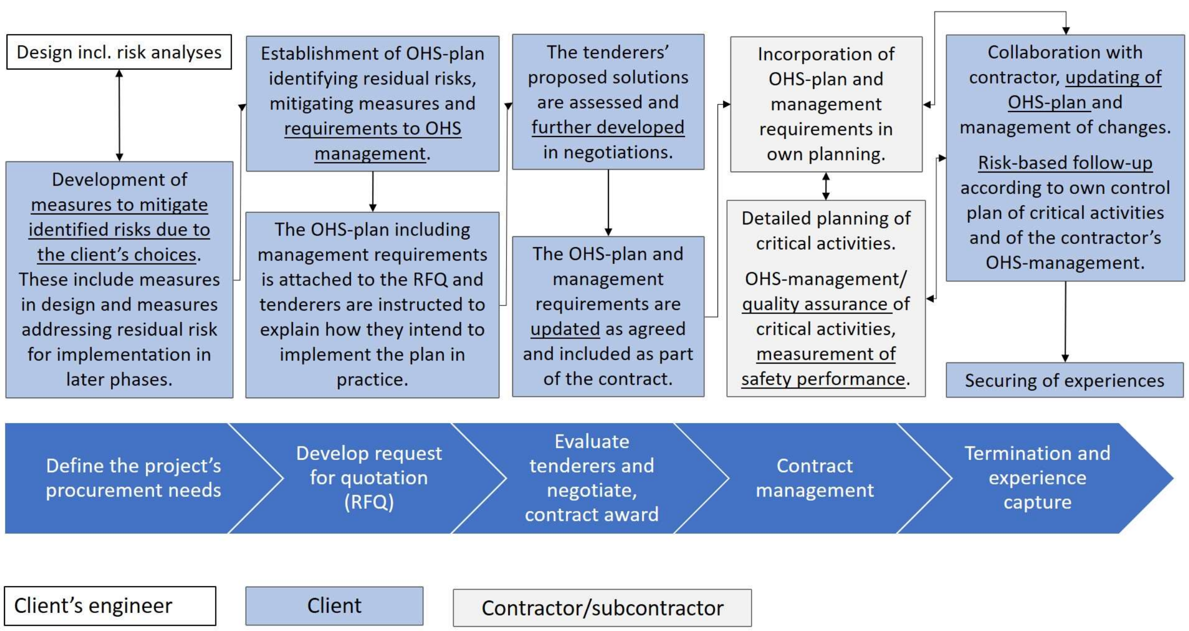

Figure 7-2. Management of barriers against accidents with severe consequences through the phases of the procurement process by applying the tools of the barrier indicator (client-centred).

The barrier management process is aligned with the obligations of a construction client to manage risks in accordance with the Construction Client Regulations. It also represents a means of ensuring the implementation of contractual safety requirements of a private law agreement between a client and contractor.

From the client's perspective, the barrier management process involves (cf. Figure 7-2 and Table 6-1):

- Use of barrier analysis during the planning and design phase of the project to design measures that remove or reduce risks that have been identified in risk analyses by the engineer. The risk analyses in this phase shall focus on the planning and engineering decisions made by the client.
- Risks not resolved during planning and design need to be documented in a register of residual risks and the OHS-plan and brought forward for management in subsequent phases of the project. In this work, barrier analysis will support in the identification of the necessary measures to mitigate the risks during production to be documented in the OHS-plan.
- The OHS-plan must be included in the request for quotation (RFQ), where the tenderers are made aware of the residual risks from planning and design and the client's proposed solutions for the management of these risks. The tenderers should be instructed to include their preferred implementation of the solutions in their quotation. The tenderers should also be instructed to describe their management system for internal control of own and subcontracted work to ensure compliance with regulatory and contractual requirements to OHS (including the client's OHS-plan). The use of the barrier indicator may be part of the client's requirements to contractor's internal control system. The client my also put requirements to transparency and traceability of the contractor's internal control system.
- Use of the negotiations with the shortlisted contractor(s) to amend and complete the OHS-plan and to resolve issues regarding implementation and follow-up through contractor's internal control. The barrier analysis and associated checklist for barrier limitations are suited tools for technical clarifications in the negotiations. This part of the negotiations represents an arena for utilising the contractor's experience in ensuring high-quality solutions and the parties' loyalty to the decisions. The results of the negotiations with the selected contractor need to be included as part of the contract.
- The tenderers' response to the request for quotation and their approach in the negotiations will also serve as useful input in short-listing and selection of contractor.
- Application of barrier analysis in collaboration with the contractor in updates of the OHS-plan during the execution phase.
- Include application by the client of the barrier indicator in the control plan for follow-up of the contract. The use of the barrier indicator needs to apply an appropriate sampling technique. The sampling scope and frequency should be based on the risks involved in the execution of contract work and experience with the contractor and subcontractors.
- Nonconformities should be addressed as agreed in the contract and resolved at the management level.
- A contractor's scores on the barrier indicator represent a valid indicator of its compliance culture and may be included in the client's experience database for use in prequalification of contractors for new contracts.

The selected contractor will have to incorporate the client's OHS-plan and management requirements according to the contract in own planning. Planning will develop at an increasing level of detail and include adaptation and application of contractor's own standard procedures for construction work as well. Although this work involves risks of which contractor has ample experience, barrier analysis may be used by contractor for quality assurance purposes. This also applies to contractor's subcontractors at any tier.

The barrier indicator is primarily valid for use by the main contractor in internal control of own and subcontractors' activities. The applications involve use in planning a few weeks before start-up of critical activities, immediately before start-up, and during execution (Table 6-1). The application during planning may involve checks that the site's intake control of personnel and equipment for the work is adequate. It is an advantage in promoting collaboration and trust to invite the client to participate in such activities.

8 Literature

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9 Attachments

9.1 Definitions and abbreviations

9.1.1 Definitions

Work-related injury

Injury due to an unexpected and sudden external event, occurring during the performance of work tasks at the workplace.

Barrier

A set of system elements (human, technical, organisational) that provide a barrier function. This function has the purpose of intervening in an accidental sequence of events to eliminate or reduce loss.

Barrier function

The ability of a barrier to intervene into the accident sequence-of-events to eliminate or reduce loss.

Barrier indicator

Method used to measure the availability of barriers against severe injury or death in construction activities based on an assessment of the availability and quality of the barriers.

Barrier index (BI)

Metric used to quantify the availability of barriers.

Hazard

A potential source of damage to health of people or damage to the environment or material assets (cf. European Council 2006). In most cases, it is an energy source with the potential of creating injury to personnel or damage to the environment or material assets.

Loss-time injury frequency rate (LTI-rate)

The frequency of work-related injuries with absence per million working hours.

Total Recordable Injury Frequency Rate (TRI-rate)

The frequency of work-related injuries per million hours worked, which results in death, disability, absence from work, medical treatment, or transfer to another job.

Safety performance indicator

Metric used to measure an organization's safety performance, i.e., its effectiveness of controlling the risk of accidents in its activities.

Lagging (delayed) safety performance indicator

An indicator that changes after the safety performance of the activity has changed. For the LTI and TRI rates, we are talking about delays of several months or more for other than construction projects with many thousands of employees.

Leading (predictive) safety performance indicator

An indicator that predicts future safety performance, i.e., that changes before safety performance change.

Real-time safety performance indicator

An indicator that changes simultaneously with changes in the safety performance of the activity. In practice, such an indicator will be somewhat delayed, but this delay must be small (i.e., a few hours or a day or two) compared to the frequency with which the activity changes.

Triangulation

In this Guide, triangulation is used as a method that utilises different data sources to check the degree of reliance that can be placed on the data and to ensure a valid result.

9.1.2 Abbreviations

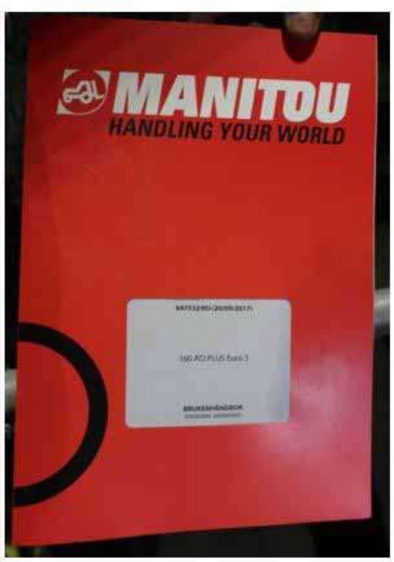
BI	Barrier index
HSE	Health, safety, environment
HTO	Human, technology, organisation
ISO	International Standard Organisation
JSA	Job safety analysis
O	Observation
OHS	Occupational health and safety
PDCA	Plan, do, check, act
T	Triangulation

9.2 Example of filled in checklist

Checklist 5, Squeezed by crane or personnel lift in motion:

	Check point	O/T	OK	Dev.	Not relev.	Contr. notified
1	Has a JSA been performed? Has it been assessed that the machine (crane or personnel lift) is suited for the lift in question and safely deployed and operated? Have the measures from the JSA been implemented?	T	X			
2	Are there instructions for the operator of the machine, which cover the relevant use, risks, and safety measures?	O	X			
3	Are the operating instructions for the machine available? Is the operator familiar with this?	T	X			
4	Are there instructions for the crew, who work with the machine, covering safety rules for work in the operating (danger) zone of the machine?	O			X	
5	Are there general safety instructions for the site that include provisions to avoid personnel movements within the danger zone of the machine?	O	X			
6	Does the operator have a machine operator license and documented machine-specific training?	T		X		
7	Do the members of the crew, who work with the machine, have training on safety rules for work in the operating area (danger zone) of the machine? Is the training based on documented instructions?	T			X	
8	Do workers in the workplace have training on safety rules to avoid moving within the operating (danger) zone of the machine? Is the training based on documented instructions?	T	X			
9	Is the machine certified?	T	X			
10	Have documented inspections and testing of the machine been carried out by competent person within the last 12 months?	O	X			
11	Has the machine been subjected to regular control and maintenance in accordance with the manufacturer's recommendations?	T		X		
12	Is the machine checked daily before use? Is this documented? If defects are identified, are the necessary measures taken to correct them?	T		X		
13	Is the personnel lift equipped with a safeguard that stops its movements when personnel risk being squeezed between the lift and roof?	O		X		
14	Is the machine used within the area of use for which it is certified?	O	X			
15	Does the operator have an adequate overview of the danger zone of the machine's movements (direct view, camera, mirror, signalman)?	O	X			
16	Is the danger zone adequately illuminated and does site personnel wear high-visibility clothing?	O	X			

#	Comments	Measures
6	The worker says he has completed a lift operator course, but documentation is not provided.	The employer shall produce documentation on the operator's completion of lift operator course and machine specific training.
11	Documentation of regular control and maintenance of the lift is missing.	The employer shall produce documentation on regular control and maintenance of the lift in question.
12	Daily check of the lift is not documented. The operating instruction for the lift defines mandatory checkpoints.	The employer shall establish system for documented daily check of machinery.
13	A squeeze protection device has not been installed.	Employer only to use lifts with installed squeeze stop.



9.3 Barrier analyses of the activities and events included in the barrier indicator

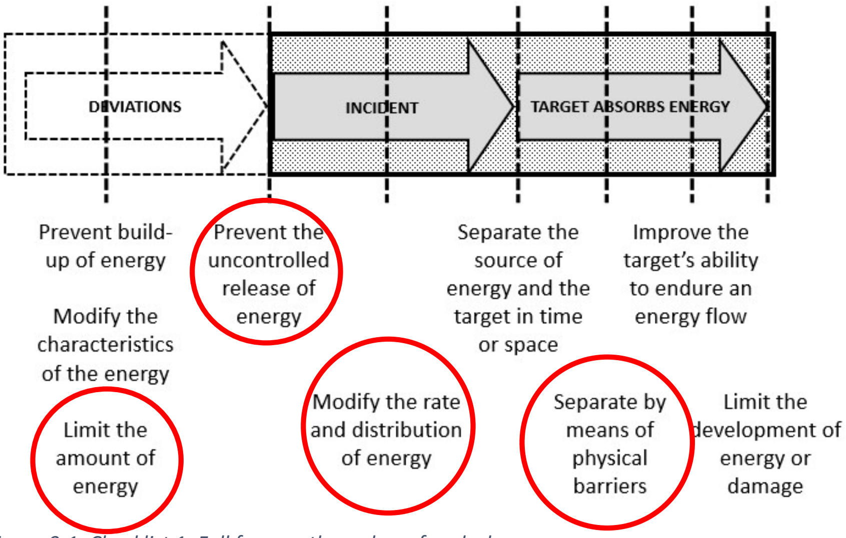


Figure 9-1. Checklist 1: Fall from or through roof or deck

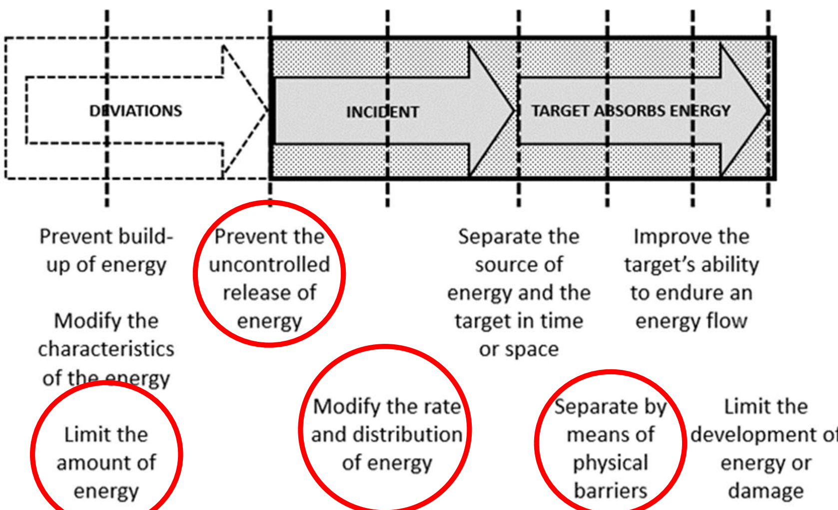


Figure 9-2. Checklist 2: Fall from machine or equipment

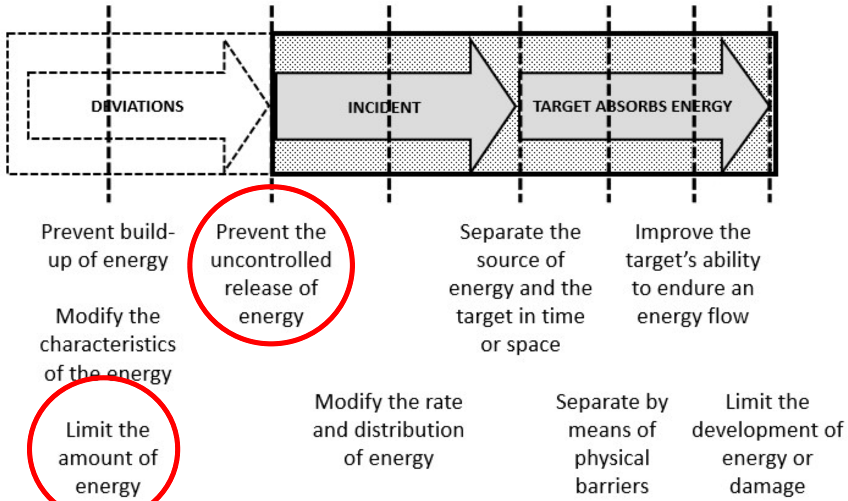


Figure 9-3. Checklist 3: Fall from inclined or free-standing ladder

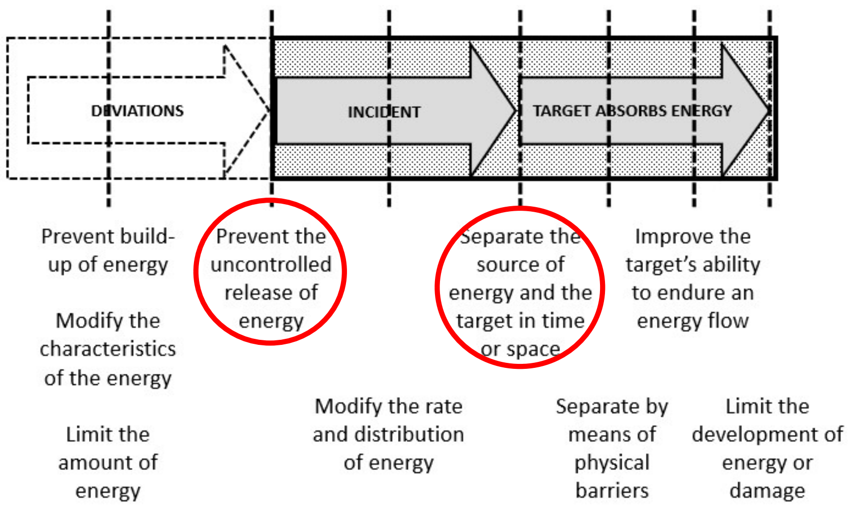


Figure 9-4. Checklist 4: Hit by load or other in connection with lifting

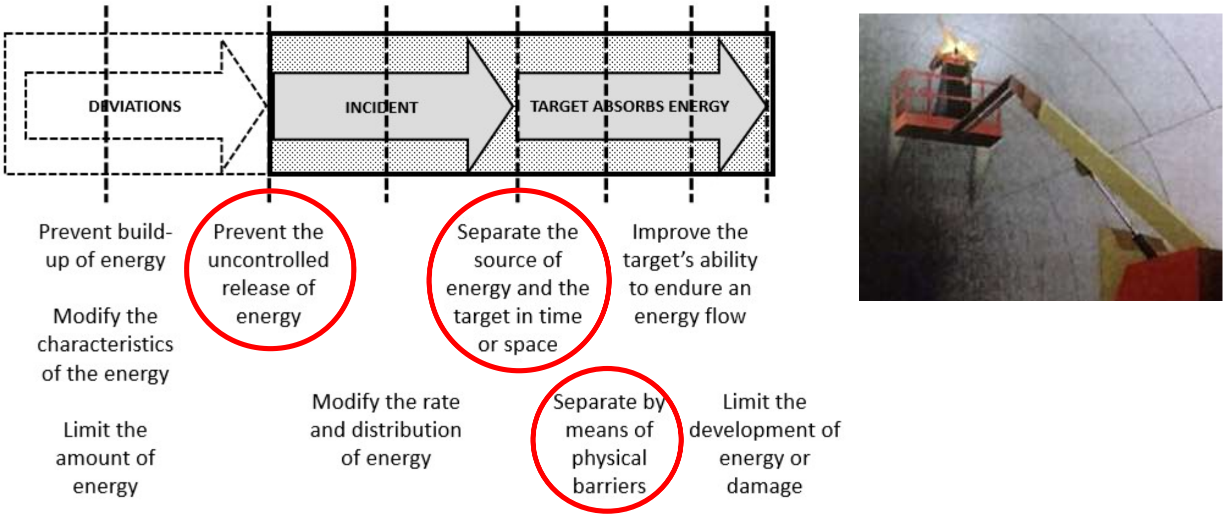


Figure 9-5. Checklist 5: Squeezed by crane or lift in motion

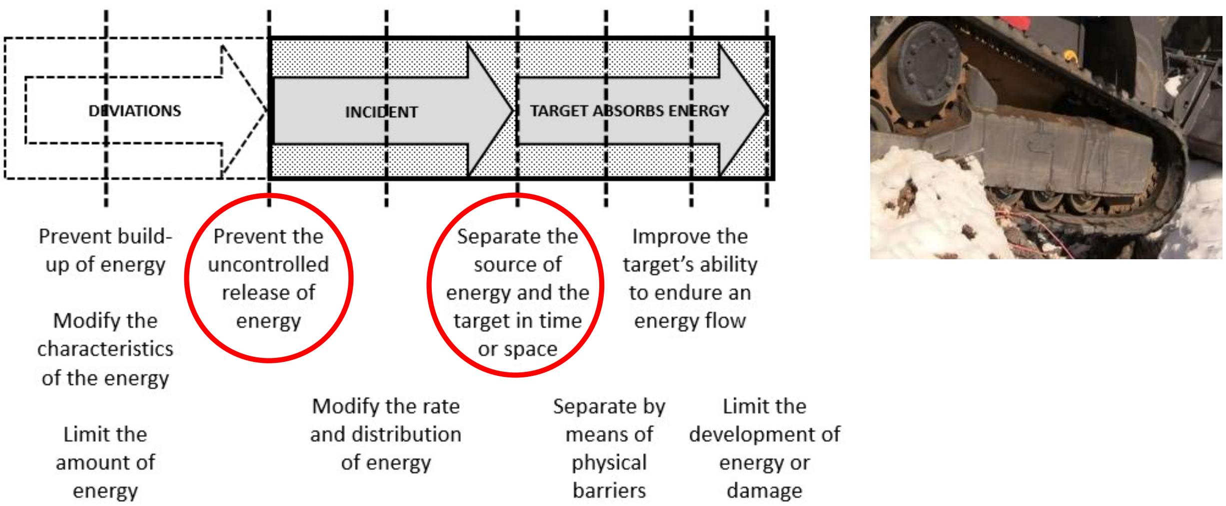


Figure 9-6. Checklist 6: Hit by construction machine

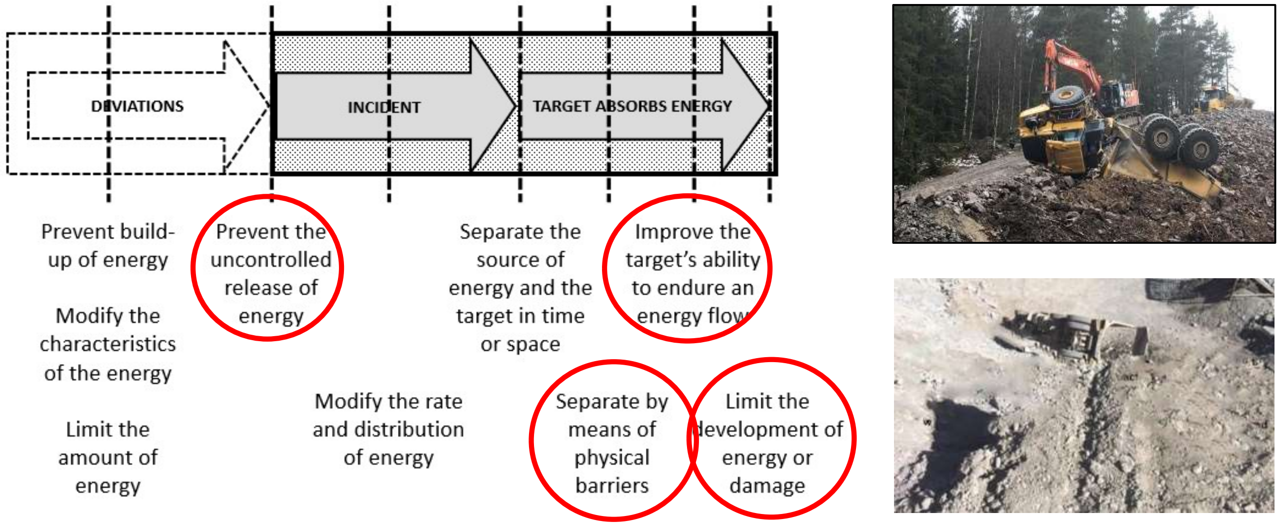


Figure 9-7. Checklist 7: Tipping over of construction machine or accidental departure from road or work area

9.4 Checklists

Barrier Indicator

User instructions and checklists

Instructions for using the barrier indicator:

The purpose of the checklists is to evaluate whether the barriers needed to avoid severe injury have been established when hazards (sources of energy) with high potential are present.

Checkpoints control through:

- O = Observation (on-site observation of the activity and interview of the workers)
- T = Triangulation (observation, document review and interview)

Steps in using the barrier indicator:

1. Identify activities to be inspected and in which periods it is relevant to carry out the inspections. A period should not exceed two weeks to allow for a reasonably timely feedback. Establish a plan for implementation based on the progress plan of the project and document this in the project's control plan.
    a. To get a representative sample, it is recommended to make five or more inspections during each period.
    b. To study developments in the barrier index, it is recommended to carry out inspections for a minimum of three periods.
2. For each activity to be examined, review the current checklist, and focus on points that require checking of documentation. Obtain relevant documents and use them in planning the inspection.
3. Carry out the inspection when relevant activity is carried out. For each activity, check the conditions at the workplace using the checklist on the front of the form and conduct the relevant observations, interviews, and document checks.
4. Review the results of each activity to identify any need for complementary information. This may apply to documents, which are still missing, or the need for further interviews with e.g., supervisors or specialists.
5. Document the results from each inspection in the designated form on the back side of the checklist. This should be done shortly after completing the inspection, preferably on the same day.
    a. For each checkpoint, clarify whether the conditions are satisfactory or not (OK / DEVIATION) or whether the point is NOT RELEVANT. Take photos, if applicable, of checked documents and of findings in the workplace.
    b. For checkpoints, where the conditions are not satisfactory, briefly describe the deviations on the back of the form. Add photos to illustrate observations (Deviations/OK).
6. Compile the results of the inspections for a period into the barrier index. Calculate for each checklist the number of checks that show OK conditions and the number of DEVIATIONS. Checks that are NOT RELEVANT do not count in the calculations. The barrier index (BI) is calculated as % OK of the sum of OK checks and DEVIATIONS:

$$BI\ (\%) = \frac{Number\ of\ OK}{Number\ of\ OK + Dumber\ of\ DEVIATIONS} * 100$$

    This can be calculated as an average for all checks in a period or for each type of checklist in the same period.
7. Follow up on individual findings in the inspections (DEVIATION) and on the result of the measurement of the barrier index.

1. Fall from or through roof or deck

Date:	Project name/no.:
Work area/ activity:	
Inspector:	

	Check point	O/T	OK	Dev.	Not relev.	Contr. notified
1	Has a JSA been carried out, which includes the choice of protection against falls when accessing the workplace and performing work at height? Is approval of the use of personal fall protection included? Have the measures from JSA been implemented?	T				
2	Are there instructions for work at height that cover current work, fall risks and safety measures (collective, personal)?	O				
3	Is the manufacturer's manual for use of personal fall protection available to the workers?	T				
4	Have the workers received training for work at height based? Is it based on documented safety instructions and user manual?	T				
5	Is personal fall protection certified (CE marked) and approved for the current work operation and fall risk?	T				
6	Are railings and coverings of openings in the deck checked by a qualified person at start-up and regularly (for example during a safety round) to avoid defects?	T				
7	Is personal fall protection checked annually by an expert?	T				
8	Is it arranged for safe access to the workplace?	O				
9	Is the work area tidy to prevent slipping or tripping?	O-				
10	Are all edges secured with railings? Are openings in the floor/deck (larger than 260/300 mm) secured with covering or railings?	O				
11	Are covers in use secured and marked? Are they designed to withstand the load in connection with the work?	O				
12	Is personal fall protection free from defects with reduced protective effect? Is it checked before use for such defects?	T				
13	Is personal fall protection used for work in areas with a fall height of more than 2m that are not secured with collective security measures?	O				
14	Is personal fall protection attached to at least one anchor point and designed so that falls are prevented or that falls are arrested in a safe manner?	O				
15	Is there a plan and equipment for rescuing people at height? Does this include people hanging in a fall protection harness?	T				
16	Is the plan for rescuing people at height implemented through regular training?	T				

#	Comments	Measures

2. Fall from machine or equipment

Date:	Project name/no.:
Work area/ activity:	
Inspector:	

	Check point	O/T	OK	Dev.	Not relev.	Contr. notified
1	Has a JSA been carried out which includes the choice of work floor for work at height from machine/equipment? Have alternatives to the present selection been assessed, i.e., work at ground floor or safe work platform? Is choice of fall protection when accessing the workplace and performing work included in the JSA. Is approval of the use of personal fall protection included (if relevant)? Have the measures from the JSA been implemented?	T				
2	Are there instructions for work at height that cover current work, fall risks and safety measures (collective, personal)?	O				
3	Are the manufacturer's instructions for use of personal fall protection available to users?	T				
4	Have the workers received training for work at height? Is it based on documented safety instructions?	T				
5	Is personal fall protection certified (CE marked) and approved for the current work operation and fall risk?	T				
6	Are railings and coverings of openings in the deck checked by a qualified person at start-up and regularly (for example during a safety round) to avoid defects?	T				
7	Is personal fall protection checked annually by an expert?	T				
8	Has it been arranged for safe access to the work area?	O				
9	Is the work area tidy to prevent slipping or tripping?	O				
10	Are all edges secured with railings? Are openings in the floor/deck (larger than 260/300 mm) secured with covering or railings?	O				
11	Are covers in use secured and marked? Are they designed to withstand the load in connection with the work?	O				
12	Is personal fall protection free from defects with reduced protective effect? Is it checked before use for such defects?	T				
13	Is personal fall protection used when working in areas with a fall height of more than 2 m, which are not secured with collective protection measures, or where there is a requirement for personal fall protection?	O				
14	Is personal fall protection attached to at least one anchor point and designed so that falls are prevented or that falls are arrested in a safe manner?	O				
15	Is there a plan and equipment for rescuing personnel at height? Does this include people hanging in a fall protection harness?	T				
16	Has the plan for rescuing people at height been implemented through regular training?	T				

#	Comments	Measures

3. Fall from inclined or free-standing ladder

Date:	Project name/no.:
Work area/ activity:	
Inspector:	

	Check point	O/T	OK	Dev.	Not relev.	Contr. notified
1	Has a JSA been carried out which includes the choice of support for the work operation at height? Is approval of the use of ladder included? Have the measures from JSA been implemented?	T				
2	Are there instructions for work at height, which cover the current use of ladder, fall risk and safety measures?	O				
3	Have the workers received training for work from ladder based? Is it based on documented safety instructions?	T				
4	Is the ladder type approved (CE marked)?	O				
5	Is the ladder located on a firm foundation and is it secured against slipping or tipping over?	O				
6	Is the use of a non-self-supporting ladder for access to roof or platform limited to a height difference of 5 meters? Does the ladder protrude at least 1 meter above this height? Is the ladder secured at the top support?					
7	If a step ladder is used for performing work at height, is it of the platform ladder type?	O				
8	Is the ladder free of defects, which results in reduced safety? Is it checked before use for such defects?	T				

#	Comments	Measures

4. Hit by falling load or other object in connection with lifting

Date:	Project name/no.:
Work area/ activity:	
Inspector:	

	Check point	O/T	OK	Dev.	Not relev.	Contr. notified
1	Is there a lifting plan for the current lift (for complex, non-routine lifts)? Does this include calculations and risk assessment if the lift is complicated?	T				
2	Has a JSA been performed? Has it been assessed that the crane (or other machine used for lifting) is suited for the lift in question and safely deployed and operated? Have the measures from the JSA been implemented?					
3	Has a person responsible for the lifting operation been designated?	O				
4	Are there instructions for the operator, signalman, and rigger, which cover the relevant lift, risks, and safety measures?	O				
5	Are the operating instructions for the machine available? Is the operator familiar with them?	T				
6	Are there general safety instructions for the site that include provisions to avoid personnel movements within the danger zone of lifting equipment and suspended loads? Do these address instructions to personnel, requirements to barriers/signage to prevent access to the danger zone, and instructions regarding signalling?	O				
7	Does the operator have a crane operator license and documented machine-specific training?	T				
8	Do the members of the lifting crew (rigger and signalman) have training on the use of lifting equipment and signalling? Is the training based on documented safety instructions?	T				
9	Do workers at the site have training on lifting operation signage and signalling and on avoiding moving within the danger zone of cranes and suspended loads? Is the training based on documented safety instructions for the site?	T				
10	Are cranes and lifting equipment certified? Are requirements for anemometer and adjustable operating limits included in crane certification? Are only interchangeable equipment used together with the crane, which fall within the declaration of conformity for the crane?	T				
11	Are lifting equipment marked for safe use?					
12	Have documented inspections and testing of crane and lifting equipment been carried out by competent person within the last 12 months?	T				
13	Has the crane been subjected to regular control and maintenance in accordance with the manufacturer's recommendations?	T				
14	Is the crane checked daily before use? Is this documented? If defects are identified, are the necessary measures taken to correct them?	T				
15	Are lifting equipment of satisfactory quality and stored in a satisfactory manner					
16	Are the crane and lifting equipment used within the area of use for which they are certified?					
17	Is the limit for maximum wind speed (12 m/s) respected during crane lifting operation?	T				
18	Is the adjustable operating limit of the crane activated in case of potential conflict with high-voltage line, other cranes, or third-party activities?	T				
19	Is the correct rigging method used to avoid loss of load?	O				
20	Does the operator or signalman have a full overview of the danger zone for suspended loads?	T				
21	Is the lifting zone adequately illuminated and does site personnel wear high-visibility clothing?	O				
22	Are lifts only carried out when the danger zone for suspended load is free from people?	O				

#	Comments	Measures

5. Squeezed by crane or personnel lift in motion

Date:	Project name/no.:
Work area/ activity:	
Inspector:	

	Check point	O/T	OK	Dev.	Not relev.	Contr. notified
1	Has a JSA been performed? Has it been assessed that the machine (crane or personnel lift) is suited for the lift in question and safely deployed and operated? Have the measures from the JSA been implemented?	T				
2	Are there instructions for the operator of the machine, which cover the relevant use, risks, and safety measures?	O				
3	Are the operating instructions for the machine available? Is the operator familiar with this?	T				
4	Are there instructions for the crew, who work with the machine, covering safety rules for work in the operating (danger) zone of the machine?	O				
5	Are there general safety instructions for the site that include provisions to avoid personnel movements within the danger zone of the machine?	O				
6	Does the operator have a machine operator license and documented machine-specific training?	T				
7	Do the members of the crew, who work with the machine, have training on safety rules for work in the operating area (danger zone) of the machine? Is the training based on documented instructions?	T				
8	Do workers in the workplace have training on safety rules to avoid moving within the operating (danger) zone of the machine? Is the training based on documented instructions?	T				
9	Is the machine certified?	T				
10	Have documented inspections and testing of the machine been carried out by competent person within the last 12 months?	O				
11	Has the machine been subjected to regular control and maintenance in accordance with the manufacturer's recommendations?	T				
12	Is the machine checked daily before use? Is this documented? If defects are identified, are the necessary measures taken to correct them?	T				
13	Is the personnel lift equipped with a safeguard that stops its movements when personnel risk being squeezed between the lift and roof?	O				
14	Is the machine used within the area of use for which it is certified?	O				
15	Does the operator have an adequate overview of the danger zone of the machine's movements (direct view, camera, mirror, signalman)?	O				
16	Is the danger zone adequately illuminated and does site personnel wear high-visibility clothing?	O				

#	Comments	Measures

6. Hit by construction machine

Date:	Project name/no.:
Work area/ activity:	
Inspector:	

	Check point	O/T	OK	Dev.	Not relev.	Contr. notified
1	Has the construction site layout and accessibility by road been the subject of a risk assessment covering the risk of collision between moving machines and running over of personnel on the site?	O				
2	Have the measures from the risk assessment been implemented? Can movement of machines, loading and unloading take place separately from work areas and pedestrian traffic?	T				
3	Are there instructions for the machine operator, which cover the selection and use of a suitable machine, risks, and safety measures?	O				
4	Are the operating instructions for the machine available? Is the operator familiar with them?	T				
5	Are there instructions for the crew, who work with the machine, with safety rules for work in the operating area (danger zone) of the machine?	O				
6	Are there general instructions for the site that include avoiding the operating area (danger zone) of the machine?	O				
7	Does the operator have an operator's license for the relevant type of construction machinery and documented machine-specific training?	T				
8	Do the members of the crew, who work with the machine, have safety training in work in the operating area (danger zone) of the machine? Is the training based on documented safety instructions?	T				
9	Do workers in the workplace have training and instruction to avoid moving within the operating area (danger zone) of the machine? Is it based on documented safety instructions?	T				
10	Is the machine certified? Are only interchangeable equipment used together the machine, which fall within the declaration of conformity for the machine?	T				
11	Have documented inspections and testing of the machine and interchangeable equipment been carried out by competent person within the last 12 months?	O				
12	Has the machine been subject to regular control and maintenance in accordance with manufacturer's recommendations?	T				
13	Is the machine checked daily before use? Is this documented? If defects are detected, are the necessary measures taken to correct them?	T				
14	Is the machine equipped with wheels/track chains with adequate grip to the surface?	T				
15	Does the surface of the machine have good enough characteristics (friction, stability, smoothness, drainage, and inclination) to ensure controlled movement?	O				
16	Is the machine used within the area of use for which it is certified?	O				
17	Does the operator have an adequate overview of the danger zone of the machine's movements (direct view, camera, mirror, signalman)?	T				
18	Is the danger zone adequately illuminated and does site personnel wear high-visibility clothing?	O				
19	Do you follow the instructions not to move in the danger zone of the machine by auxiliary personnel? By other workers in the workplace?	T				

#	Comments	Measures

7. Tipping over of construction machine or accidental departure from road or work area

Date:	Project name/no.:
Work area/ activity:	
Inspector:	

	Check point	O/T	OK	Dev.	Not relev.	Contr. notified
1	Has the construction site layout and accessibility by road been the subject of a risk assessment covering the risk of tipping over or departure from road or work area by construction machine? Does this consider special conditions, e.g., the quality of temporary (bypass) roads?	O				
2	Have the measures from the risk assessment been implemented?	T				
3	Are there instructions for the machine operator, which cover the selection and use of a suitable machine, risks, and safety measures?	O				
4	Are the operating instructions for the machine available? Is the operator familiar with them?	T				
5	Does the operator have an operator's license for the relevant type of construction machinery and documented machine-specific training?	T				
6	Is the machine certified? Are only interchangeable equipment used together the machine, which fall within the declaration of conformity for the machine?	T				
7	Is it documented that the construction road has been dimensioned for the actual transportation needs in construction?	T				
8	Have documented inspections and testing of the machine and interchangeable equipment been carried out by competent person within the last 12 months?	O				
9	Has the machine been subjected to regular control and maintenance in accordance with the manufacturer's recommendations?	T				
10	Is the machine checked daily before use? Is this documented? If defects are detected, are the necessary measures taken to correct them?	T				
11	Are surfaces used by the machine subject to regular inspection and maintenance? Are the surfaces cleared for snow and litter at an acceptable frequency?	T				
12	Is the machine equipped with wheels/track chains with adequate grip to the surface?	O				
13	Do the surfaces used by the machine have good enough safety characteristics with respect to friction, stability, smoothness, drainage, and grade to ensure controlled movement?	O				
14	Are unstable edge zones on construction roads and work areas used by the machine clearly marked or protected by guardrails where road departures may have severe consequences?	O				
15	Is speed managed by speed limits, speed dumps, or constrictions?	O				
16	Is the dump site equipped with a dump berm or dumping machine to avoid backing over the edge of the dump?	O				
17	Is the machine used within the area of use for which it is certified?	O				
18	Are the instructions for safe use of the machine respected? Are the speed limits complied with?	T				
19	Is a suitable life jacket (e.g., inflatable, manual release) in use when driving in an area with a risk of driving into water? Has the operator received training in the use of this?	T				

#	Comments	Measures

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