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Barrier Management in Construction Projects

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The construction industry is one of the most accident-prone industries in Norway, both in terms of occupational injuries and fatalities. As all accidents can be explained as the transfer of energy to a victim, accident prevention must focus on controlling the energy that can cause harm. There are several factors that influence the extent of an injury: the amount of energy, the way the energy is transferred, and the robustness of the victim. Barrier management involves systematically and continuously ensuring that necessary barriers are identified and implemented to prevent unwanted incidents with high damage potential. Hence, we argue that barrier management must be risk-based to identify prioritized high-energy events. This paper presents a guide and a tool for barrier management in construction projects, supporting construction clients, designers and contractors in identifying, evaluating and following-up barriers in a structured manner. The work has been carried out in close collaboration with industry stakeholders.

Keywords: Barrier management, barrier analysis, barrier follow-up, barrier function, human barrier element, technical barrier element, organizational barrier element, construction industry.

1. Introduction

Worldwide, the construction industry is one of the industries with the highest frequency of severe occupational accidents. To reduce the number of severe accidents, a study in the Norwegian construction industry recommended taking steps to increase competence in effective interventions and risk-reduction approaches, such as safety barriers and barrier management (Winge et. al., 2025). To support this recommendation a guide and a tool for barrier management in construction projects were developed. The result of this development is presented in this paper. Barrier management has been a key to prevention in many industries (process industry, nuclear power plants, petroleum industry); however, it is not used extensively within the construction industry.

The development of the tool and the guide was based on research literature on barrier management, the authors' own experience, and input from industry stakeholders. The work was carried out in the following phases: (1) preparation of a draft version of the tool; (2) presentation, testing, and discussion of the tool during a workshop organized by the research project SIBA; and (3) further development of the tool based on feedback from the industrial partners in the SIBA project.

2. Prevention of accidents as a transfer of energy

Accidents occur when people, equipment, or the environment are exposed to "uncontrolled energy" that is not prevented or managed by barriers (Gibson, 1961). All accidents can be explained as a transfer of energy to a victim. On a construction site, many different types of energy may be present that can cause harm. Work during the production phase in the construction industry is characterized by high energy levels associated with, for example, large vehicles in motion, working at heights, the use of explosives, lifting operations, and electricity. These forms of energy are necessary for projects to achieve their objectives. At the same time, all accidents in the construction industry can be explained as a loss of control over these energies, which in turn leads to harm.

2.1. *Energy and barriers to prevent harm*

Often illustrated as 'the energy wheel' (Fig. 1) hazardous energies are typically grouped into ten categories: gravity, motion, mechanical, pressure, biological, temperature, chemical, electrical, radiation, and sound.

To prevent the release of energy leading to accidents, effective barrier functions must be established that prevent, stop, or reduce the transfer of energy so that harm is avoided, see Figure 1.

A barrier is a function that prevents, stops, or reduces the transfer of energy in order to prevent an event sequence from occurring or developing, to influence an event sequence in an intended direction, or to limit damage and/or loss (Kjellén and Albrechtsen, 2017).

A barrier function is realized through barrier elements. Barrier elements may be human (man), technical, or organizational (MTO). Together, the combination of these elements constitutes the barrier function (the task).

According to a study of incidents by Hallowell (2025), energies above 1500 Joules represent a threshold for serious consequences, i.e., fatalities or severe injuries. However, not all serious accidents involve energies above this

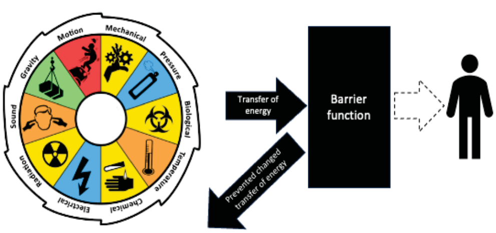

Fig. 1. Barrier as a function that prevents, stops, or reduces energy transfer and thereby prevents or limits harm to the victim.

level, and events exceeding 1500 Joules may still result in less severe outcomes.

2.2. *Haddon's strategies*

Haddon (1973; 1980) described ten generic strategies for reducing damage associated with all types of hazards (Table 1). Strategy 1-4 are aimed at removing the hazard, reducing the hazard, or ensuring control of the hazard so that harmful energy is not released uncontrollably. If it is not possible to eliminate or reduce the risk to an acceptable level, physical measures can be used, or the hazard and the victim can be separated in time and space (strategy 5-6). The last four strategies (7-10) are primarily directed at reducing harm. Some measures may fit under several strategies, and the intention is not to place all measures unambiguously, but to support a systematic and creative process for finding good combinations of strategies and measures.

Table 1. Haddon's (1980) generic strategies for damage reduction

No.	Strategy
1	To prevent the creation of the hazard in the first place
2	To reduce the amount of the hazard brought into being
3	To prevent the release of the hazard that already exists
4	To modify the rate or spatial distribution of release of the hazard from its source
5	To separate, in time or space, the hazard and that which is to be protected
6	To separate the hazard and that which is to be protected by interposition of a material "barrier"
7	To modify relevant basic qualities of the hazard
8	To make that to be protected more resistant to damage from the hazard
9	To begin to counter damage already done by the environmental hazard
10	To stabilize, repair, and rehabilitate the object of the damage

Haddon's strategies encourage a fundamental way of thinking about the processes by which injuries occur and the ways in which they can be prevented (Runyan and Baker, 2009). The strategies are not mutually exclusive, and combinations of measures are often recommended (Winge and Albrechtsen, 2018).

Research on safety barriers in the construction industry remains limited. An exception is the analysis of 176 construction accidents conducted by Winge and Albrechtsen (2018), which found that many accidents involved either no physical barrier failures – only human errors – or situations where a single physical barrier served as the only line of defense. When that barrier failed, such as in cases of missing guardrails or scaffold collapse, nothing else prevented serious injury. This underscores the need for multiple, redundant barriers, consistent with the defense-in-depth philosophy described by Reason (1997). The analysis also identified many opportunities to implement countermeasure strategies across different stages of the accident process, as outlined by Haddon (1980).

2.3. *Barrier management and risk management*

To establish, maintain, and follow up barriers so that they are always capable of performing their function, barrier management is required (PSA, 2017). Barrier management consists of coordinated activities to establish and maintain barriers so that they consistently fulfil their intended function. Barrier management therefore includes barrier analysis, implementation of the barriers, and the follow-up of the barriers.

Barrier management is a part of risk management. Barriers should be established when the risk management process identifies failures, hazards, and accident scenarios where there is a need for additional protection (PSA, 2017). A fundamental principle in barrier management is that barriers must be directly linked to a concrete and situation-specific risk picture. In construction projects, this involves identifying which work operations and situations may lead to serious incidents, such as work at heights, heavy lifting, and interactions between people and machinery.

3. Steps of Barrier Management – a Guide

Figure 2 shows the steps in the developed framework for barrier management in the construction industry. In the following, we describe each of the steps.

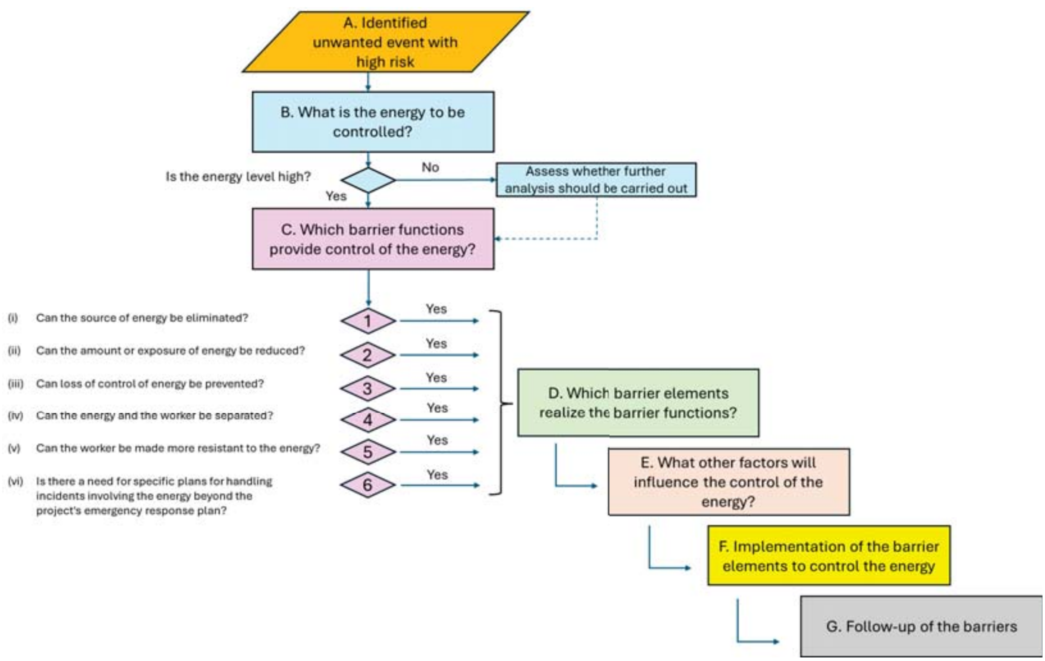

Fig. 2. Flowchart for barrier management in construction projects

3.1. *Step A – Identified unwanted event with high risk*

It is recommended to identify 3-5 types of high-risk events in a construction project for which a barrier analysis should be carried out. These will typically be work operations with high energy potential, meaning a high consequence combined with an expected frequency.

It is essential to assess which hazards and risk conditions are most relevant for barrier management based on the risk profile of each individual project. However, relevant events for barrier management could for example include falling objects, fall from heights, human–machine interaction, electrical voltage, structural failure, or explosions; all identified as high-risk events by national interest organizations in Norway. [a]

3.2. *Step B – What is the energy to be controlled?*

For the identified unwanted event from step A, the energy source that must be controlled, and therefore analyzed, is identified. One way of doing so is to use the energy wheel (Fig. 1). Note that in some potential events, there may be more than one energy source that needs to be managed through barriers.

The amount of energy influences the extent of the damage. A control question at this stage of the analysis is therefore whether the event being analyzed involves high energy. Examples of high-energy events include explosions, falls from heights over 2 meters, a car traveling at more than 50 km/h, a truck traveling at more than 2 km/h, the use of any heavy equipment with rotating parts, a 15-kg load lifted 10 meters above the ground, and unprotected edges in a trench deeper than 1.5 meters (Hallowell, 2025).

3.3. *Step C – Which barrier functions provide control of the energy?*

For the energy identified in step B, one must examine which barrier functions – that is, which tasks – provide control over the energy. The barrier functions are therefore directed toward a specific sequence of events and a specific energy source.

[a] "Om Prosjekt Fareblind", SfS BA, accessed February 4, 2026, https://sfsba.no/om-prosjekt-fareblind.

To support the identification of the barrier functions, the analysis consists of six questions based on in prioritized order:

(i) Can the source of energy be eliminated?
(ii) Can the amount or exposure of energy be reduced?
(iii) Can loss of control of energy be prevented?
(iv) Can the energy and the worker be separated?
(v) Can the worker be made more resistant to the energy?
(vi) Is there a need for specific plans for handling incidents involving the energy beyond the project's emergency response plan?

These questions, which are based on Haddon's (1980) generic strategies for damage reduction (see Table 1), are further discussed in the following sections.

3.3.1 *Eliminating the source of energy*

The first thing to examine is whether the hazard can be removed. This can be done by avoiding the activity altogether, thereby eliminating the energy that could cause harm. Examples include preventing the creation of potential energy by avoiding work at height or preventing the creation of thermal energy by avoiding the use of ignition sources. One can also remove the hazard by replacing, for example, dangerous chemicals, machines, and equipment with something harmless. However, this can be difficult, and often not possible, as the activity and the energy being addressed are often necessary to achieve the objectives of the construction project.

3.3.2 *Reducing the amount or exposure of energy*

Reducing the amount of energy or modifying the way the energy is transferred will help reduce the transfer of energy and thereby limit harm. This involves examining whether the activity can be carried out in a different way. Examples could be to lower vehicle speed or to reduce the quantity of chemicals stored in the same location. Exposure can also be reduced by limiting the number of hours spent working at height.

3.3.3 *Preventing the loss of control of energy*

When energy has built up as part of an activity, it must be kept under control. As long as the energy remains controlled, no harm will occur. A clear example of this is related to lifting operations. Any lifted object contains gravitational energy, as well as kinetic energy if it is moved horizontally. As long as the load is kept under control through, among other things, correct equipment, use of signal man and correct slinging, unintended transfer of energy cannot take place.

3.3.4 *Separating the energy and the worker*

Even when energy sources are under control, an uncontrolled release of energy may still occur. In such cases, it is important that the worker is separated from the energy. This can be achieved by separating them in time and space, or by using physical barriers. Establishing danger zones, implementing work permits, enclosing electrical energy through cabling, and separating pedestrian workers from vehicles are all examples of this type of barrier function.

3.3.5 *Making the worker more resistant to the energy*

The severity of harm is also influenced by how resistant the worker is to the specific type of energy. Personal protective equipment contributes to this. It is important to assess which types of protective equipment are effective against the particular hazard. Examples include the use of specialized masks when exposed to hazardous substances, or the use of fall-protection equipment when working at height.

3.3.6 *Specific plans for handling incidents involving the energy*

When harm has occurred, barriers must also be in place to reduce the consequences associated with the energy involved. Measures of this kind are largely covered by standard project notification and emergency response plans, but there may be specific considerations that require additional planning. An example could be construction work in remote areas, where reliable communication equipment with adequate coverage is needed, dedicated transport may be required to evacuate personnel, or workers may need to be equipped with avalanche beacons in areas with avalanche risk.

3.4. *Step D – Which barrier elements realize the barrier functions?*

The next step involves identifying which barrier elements must be in place to realize the barrier function identified in step C. These are elements identified during design and planning to ensure that the necessary barrier functions are in place before work begins. These elements are also essential for determining what needs to be monitored after implementation to assess whether the barrier function is working in practice. The barrier elements may relate to people, technology, or organizational factors:

- *Human barrier elements*: the actions or activities that personnel must perform to ensure the realization of a barrier function
- *Technical barrier elements*: equipment, materials, and technical systems that contribute to the realization of a barrier function
- *Organizational barrier elements*: organizational factors that contribute to the realization of a barrier function (such as planning, procedures, and management)

Examples of barrier elements to control the energy associated with suspended loads during crane lifting operations are presented in Figure 3.

Barrier function		Barrier elements
(iii) Can loss of control of energy be prevented?	Yes	Proper lifting equipment (T)
		Maintenance of the crane and equipment (O)
		Appropriate competence of involved workers (M)
		Lift planning (O)
(iv) Can the energy and the worker be separated?	Yes	Establishment of an exclusion zone in accordance with procedures (O)
		Available equipment (T)
		Danger zone is respected (M)
(vi) Is there a need for specific plans for handling incidents involving the energy beyond the project's emergency response plan?	Yes	Approved equipment for lifting an injured person out of the excavation pit using a tower crane (T)
		Plan and assessment for exceptional personnel lifting (O)

Fig. 3. Examples of barrier elements to control energy associated with crane lifting operations. M = human (man), T = technical, O = organizational

3.5. *Step E – What other factors will influence the control of the energy?*

There may be additional factors affecting energy control that are not captured through steps C and D. For such factors, it is necessary to determine the measures required to ensure effective control.

Examples of such other factors related to suspended loads during crane operations could be potential conflicts between lifting zones of multiple cranes, periodic high winds, poor lighting during the winter season, and simultaneous work activities.

3.6. *Step F – Implementation of the barriers*

This step involves using the insights from the barrier analysis (i.e., step A-E) to develop a concrete plan for:

- How barrier elements will be implemented
- Who is responsible for implementing them
- The deadline for when they must be in place

3.7. *Step G – Follow-up of the barriers*

A plan for the follow-up of the barriers must be established, grounded in the barrier analysis and the identified barrier elements. It is important that the follow-up of barriers in the project is of high quality. This includes, among other things, ensuring that responsibility for the follow-up of each barrier element is clearly defined. The level of detail in the follow-up must be adapted to the specific project.

3.7.1 *Checkpoints*

One must begin by identifying what needs to be examined, i.e., checkpoints. This is done by using information from the barrier analysis. The following aspects must be included:

- B. Energy: A fundamental question in the follow-up is whether the barriers actually provide control of the energy. A key checkpoint is therefore: "Has there been unwanted events where there has been loss of control of the associated energy?"
- D. Barrier elements: For each implemented barrier element, one must identify what should be checked in order to assess whether the element is implemented and functioning.
- E. Other influencing factors: For measures related to identified influencing factors, checkpoints must be defined to verify that the measures are implemented and functioning.
- In addition, it should be assessed whether new factors have emerged that may affect control of the relevant energy.

3.7.2 *Method*

Here, the method or methods for examining the checkpoints is determined. Examples of methods can be inspection combined with conversations at the construction site, review of incident reports, equipment inspections, and document reviews. It is often beneficial to combine several methods for each checkpoint for triangulation.

3.7.3 *Results*

Use the checklist and the methods to assess whether the relevant energy is under control.

3.7.4 *Measures*

If deviations (errors or deficiencies) are identified, or if new conditions requiring control are discovered, the necessary measures must be defined. For each measure, a responsible person must be appointed.

4. The Tool for Barrier Management in Construction Projects

The tool consists of two Excel worksheets. These follow the same structure as the flowchart in Figure 2; thus, corresponding to the steps described in Section 3: *Part I. Barrier analysis* (steps A–E) and implementation (step F), see Figure 4. *Part II: Follow-up of barriers* (step G), see Figure 5.

5. Roles and Responsibilities in Barrier Management for Construction Projects

The methodology for barrier management described in this paper can be used by all actors in the industry; however, the areas of use would differ. Clients can use it to identify barriers that must be implemented to maintain control over project-specific risk conditions and associated energy sources, as well as to follow these up as checkpoints during the production phase.

Designers can use the barrier analysis to identify which barriers must be implemented to control the risk conditions and associated energy sources they introduce through their choices in the design phase.

Contractors can use the barrier analysis to identify which barriers must be in place to control the energy before starting activities, including Safe Job Analysis (SJA). It can also be used as part of SJA. Follow-up of identified barriers can be carried out as part of inspections, safety rounds, and incident report analysis, or it can take place during meeting such as morning meetings and foreman's meetings.

At the sharp end, workers' daily or periodic checks of identified barriers – for example, inspection of machines or vehicles before use – can be included as part of the systematic barrier follow-up.

Part I. Barrier analysis & implementation				
Analysis carried out (date):				
Carried out by:				
Activity and area *Activity/area that the barrier analysis is carried out for*				
A. Unwanted event *Assessed as an unacceptable risk in the risk assessment*				
B. Energy *Energy that may cause harm (see the energy wheel)*				
C. Barrier functions (strategies) ***Which tasks provide control of the energy?***	**Yes/no**	**D. Barrier elements** ***If yes: What will realize control of the energy in Step C?***	**F. Implementation** ***Responsibility***	***Performed***
(i) Can the source of energy be eliminated?		*(Insert text)*		
(ii) Can the amount or exposure of energy be reduced?				
(iii) Can loss of control of energy be prevented?				
(iv) Can the energy and the worker be separated?				
(v) Can the worker be made more resistant to the energy?				
(vi) Is there a need for specific plans for handling incidents involving the energy beyond the project's emergency response plan?				
E. What other factors than the ones described in C will influence the control of the energy?		***What will realize control of the influencing factors in E?***		
		(Insert text)		

Fig. 4. Barrier Management Tool – Part I. Barrier analysis and implementation (excerpt from Excel worksheet)

Part II. Follow-up of barriers					
Activity and area *Activity/area that the barrier analysis is carried out for*					
A. Unwanted event *Assessed as an unacceptable risk in the risk assessment*					
G. Follow-up of barrier	**Check-points** What to examine?	**Method** How to examine?	**Results**	**Measures**	**Responsible**
B. Energy					
D. Barrier elements					
E. What other factors than the ones described in C will influence the control of the energy?					
Are there new factors that have emerged that may affect control of the energy?					

Fig. 5. Barrier Management Tool – Part II. Follow-up of barriers (excerpt from Excel worksheet)

6. Concluding Remarks

This paper presents a guide and a tool for barrier management in construction projects, supporting construction clients, designers and contractors in identifying, evaluating and following-up barriers in a structured manner.

Although the barrier approach is most commonly applied in high-risk industries, we believe that a systematic barrier management perspective is also highly relevant for preventing severe accidents in construction. However, barrier management can be complex and resource demanding, and the construction industry does not have the same traditions, levels of competence, or resources for systematic accident prevention as many high-risk sectors. Therefore, we found it useful to develop a barrier management tool specifically adapted to the needs and context of construction projects.

The work has demonstrated how Haddon's (1980) strategies and the principle of defense in depth can be used as a framework for structuring risk-reduction measures, and how barrier functions are realized through the interaction of human, technical, and organizational barrier elements. Barrier management is not only about identifying measures, but also about ensuring coherence, clear responsibilities, and systematic follow-up to verify that barriers function as intended in practice.

To identify effective combinations of barrier functions and barrier elements, it is essential to involve relevant stakeholders and individuals with diverse competence and experience, including those from management, planning, and execution. Barrier management is resource-intensive and should therefore be directed toward events with high energy potential and severe consequences. When applied in a targeted way and through collaboration among actors, the methodology can contribute to more robust solutions and reduced reliance on human behavior. One limitation of this work is that it has not yet been thoroughly tested or validated in practice.

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