# The Essence of Integral Safety Engineering for Society

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## Abstract

This paper provides an overview of Integral Safety Engineering for Society. Safety is a fundamental concern for any society, and in the Netherlands, the responsibility for managing safety and risk protection is distributed across various national government authorities. Safety-related legislation and regulations are organized into specific domains; however, these regulations are typically not intersectoral, are not based on geographic considerations, and are only minimally integrated into the life cycle of structures or the construction process. Furthermore, they are seldom aligned with national spatial planning strategies or urban development plans. While the introduction of new environmental laws has fostered increased interaction between safety domains, a unified, comprehensive approach to safety remains lacking. From a societal perspective, it is essential to adopt both a holistic view of all safety domains and ensure their integration to manage safety risks in a socially responsible, acceptable, and tolerable manner.

**Keywords:** Safety Engineering; Safety; Urban Development; Regulations.

## 1 Introduction

Safety is a fundamental concern in society and the built environment. In the Netherlands, the responsibility for safety and risk protection is distributed among various national government authorities. Safety legislation and regulations are structured by specific domains; however, they are not intersectoral, geographically coordinated, or well-integrated into the life cycle of structures, the construction process, or national spatial planning and urban development strategies. From a societal perspective, it is essential to adopt a comprehensive view of all safety domains and ensure their integration to keep safety risks socially responsible, acceptable, and tolerable. In practice, many safety risks—whether affecting individuals or large groups—can be prevented or mitigated through proactive safety measures. Embedding these measures into national spatial planning strategies, master plans, and urban designs from the earliest stages of construction significantly enhances public safety. Therefore, a holistic, integrated approach to safety across various domains is crucial. This paper explores the core principles of Integral Safety Engineering for Society.

## 2 Regulations for safety in The Netherlands

The *right to be safe* was originally enshrined as a fundamental principle in the Dutch Constitution of 1798, introduced during the French Revolution.

It stated: *"The security of the person, life, honour, and property."* However, this provision was later removed. Despite the absence of an explicit *right to safety* in the current Dutch Constitution, the government continues to provide a certain level of protection against safety risks. These include threats such as flooding, hazardous substances in the living environment [1], and risks faced by employees or users of public infrastructure. For example, the Dutch Tunnel Act mandates safety measures in, on, and around tunnels to ensure an acceptable level of protection for tunnel users [2].

Additionally, ministerial regulations are regularly introduced to enhance public safety. For instance, the Regulation Stimulating Road Safety Measures 2022-2023 ensures a certain level of protection for road users by mandating safety measures along or near roads. In the built environment, structural safety standards—such as the Eurocodes—help safeguard building occupants by ensuring structural integrity [3,4]. Moreover, EU Directive 92/57/EEC [5] sets minimum safety and health requirements for temporary and mobile construction sites. These laws, spanning both social and physical domains, are designed to mitigate risks and protect the public. However, as noted by Ale [6] and Vlek & Stallen [7], achieving absolute safety is neither feasible nor entirely realistic.

In the Netherlands, responsibility for safety and protection against risks is distributed among various governmental bodies, each overseeing specific areas:

- External safety, transport of hazardous substances, and regulations for the market introduction and emission of substances: Ministry of Infrastructure and Water Management (IenW). See e.g. Figure 1.
- Tunnel safety, ensuring user safety: Ministry of Infrastructure and Water Management (IenW).
- Safety and health of employees in companies, including frameworks for clients and contractors: Ministry of Social Affairs and Employment (SZW).
- Safety of consumer products, cosmetics, food contact materials, and toys: Ministry of Health, Welfare, and Sport (VWS).
- Safety of buildings, prevention and response to disasters: Ministry of the Interior and Kingdom Relations (BZK).
- Safety situation around hazardous companies: Provinces and municipalities. They ensure that environmental permits meet the external safety requirements and control emissions of substances.
- Traffic safety on roads: Provinces and municipalities.
- Municipalities are responsible for building and housing supervision: They inspect structural safety, fire safety, and building physics when granting building permits for new constructions.

The enumeration above provides valuable insight into how safety-related laws and regulations are structured within distinct safety domains. However, these regulations do not follow an integrated approach to safety; they remain largely sector-specific and do not consider factors such as geographical coordination, the building lifecycle, or the construction process.

Although the introduction of the new Environmental Planning Act has encouraged greater interaction between safety domains, a truly holistic and comprehensive approach to safety is still lacking. Integral safety requires cross-domain integration, yet how collaboration across different sectors functions remains an area of limited knowledge. This gap is particularly significant in understanding how integral safety is applied throughout the construction process.

Moreover, the law is often a reaction to situations where things have gone wrong [8,9]. A good example is Law 229 from the Code of Hammurabi in Babylon, which states that if a builder constructs a house for someone and it is not done properly, leading to the collapse of the house and the death of the owner, then the builder shall be put to death. This law represented significant progress at the time, addressing lawlessness, resolving disputes, and likely causing people to think twice before causing harm to others.


*Figure 1. Transport of hazardous materials on raod*

The legislator, the competent authority, the owner of the building, the client, the designer, the builder/contractor, the specialists, and the users all responsible when it comes to safety.

The lack of an integrated approach to regulations regarding integral safety is also evident around external safety. With a population density of 529 people per km² in the Netherlands [10], preserving the remaining "empty" areas is a key concern—especially to maintain recreational spaces for residents of the densely populated cities. As a result, future projects should ideally be developed within existing urban boundaries, maximizing the efficient and effective use of urban space. However, as previously mentioned, the responsibility for different integral safety domains is distributed across various governmental bodies.

## 3 Safety policy in The Netherlands

Safety policies in the Netherlands are based upon the individual risk norm of $10^{-6}$ -which is the probability being killed per year- depending on the type of safety domain and policy (see Table 1; [11]). These variations are partly influenced by historical contexts within ministerial departments and political reactions to accidents, leading to the creation of "policy windows" that focus on specific risks without fully considering the broader context. The regulations for land-use planning near major industrial hazards or transport routes for hazardous materials—often referred to as external safety protection for third parties—are explicitly risk-based [12,13]. This approach considers both the potential physical effects of incident scenarios and the likelihood of their occurrence, along with the possible impacts.

*Table 1. Safety policies in the Netherlands [11]*

| **Type of safety policies** | **Dutch legal norm for IR?** |
|---|---|
| external safety | $10^{-6}$, seen as sub risk of all industrial risks |
| aviation safety | no norm but in practice lower than $10^{-6}$ |
| water safety (dikes) | $10^{-5}$ |
| traffic safety | political acceptance of $10^{-4}$ |
| exposure to hazardous substances | $10^{-6}$ per class of substances |

The primary reason for adopting this risk-based policy in the Netherlands is the scarcity of space, it is impossible to maintain the maximum safe distance between risk-generating activities and urban development, that would be needed in the event of a worst-case scenario. As a result, a certain level of risk must inevitably be accepted [13].

## 4 Integral safety approach

Safety policy covers a wide range of activities. In practical cases an integral approach is necessary.

### 4.1 Division social and physical safety

In Vrouwenvelder's survey [14], safety is defined as the state of being adequately protected against harm or injury, free from danger or hazard. When considering the philosophy of safety, it can be classified into social safety and physical safety [15]. See figure 2. Social safety primarily involves behaviours among individuals, including factors like crime, spatial elements, institutional influences, and social dynamics within an area [16]. On the other hand, physical safety refers to the likelihood of a person being killed or injured by natural hazards, such as severe weather, earthquakes, and floods, as well as man-made hazards like traffic accidents, incidents involving the transport of dangerous materials, and accidents at nuclear reactors. It is also important to note that the consequences of failures, such as cost increases, delays, loss of quality, and environmental damage, are also part of physical safety.

In some cases, such as with fire or terrorism, classifying safety can be more complex. Physical safety can be further subdivided into internal safety and external safety, as depicted in Figure 2.

### 4.2 Geographical approach towards safety

Bruggeman & Hoogendoorn [17] present a geographical classification of integral safety, which distinguishes between (1) object safety, (2) safety at the construction site, and (3) safety in the surrounding area. This classification highlights that an object is situated within a specific built environment or vicinity, often surrounded by roads or other buildings, many of which are in use during the construction phase. See figure 3.

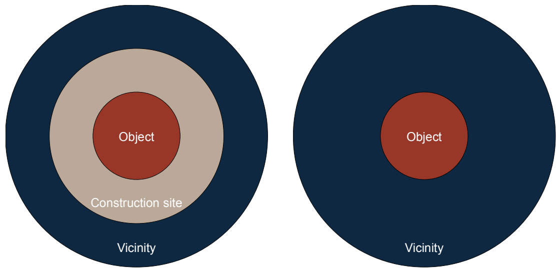


*Figure 3. Geographical approach towards safety.*

| | | | | |
|---|---|---|---|---|
| Integral safety | Physical safety | Man-made hazards | Internal safety | Internal safety of buildings |
| | | | | Traffic safety |
| | | | | Labor safety |
| | | | | Tunnel safety |
| | | | | Fire safety |
| | | | | Transport safety |
| | | | | Construction safety |
| | | | External safety | Stationary installations |
| | | | | Windmills |
| | | | | Aviation safety |
| | | | | Transport van hazardous materials |
| | | Natural hazards | | Floods |
| | | | | Earthquakes |
| | | | | Meteorites |
| | | | | Remaining climatic factors |
| | | | | Diseases and epidemics |
| | Social safety | | | Terrorism |
| | | | | Criminology |
| | | | | Institution |
| | | | | Design |
| | | | | Sociology |
| | | | | Perception |

*Figure 2. subdivision of integral safety.*

During the construction or renovation of a building, a construction site is established, typically enclosed by a fence, which is usually located within the same vicinity. In this chapter, we adopt the definitions from the Dutch Operational Framework for Safety Management in the Construction Process [18] to address (1) object safety, (2) safety at the construction site, and (3) safety in the surrounding area. The advantage of this approach is that it enables an integrated view of safety, ensuring that object safety, construction site safety, and the safety of the surrounding area are all considered together within a project.

# 5 Case study: the renovation of the Wantij bridge

## 5.1 General information about the bridge

The Wantij bridge (see figure 4) is a bascule bridge in the Netherlands, located on the N3 highway between Papendrecht and Dordrecht. The bridge spans the Wantij River.

The bridge is designed as a bascule bridge with fixed approach spans that cross the Wantij River. The southern approach span is 110 meters long and features a central pier in the river, while the northern approach span is approximately 25 meters long. The Wantij is a small tidal river, from which the name Wantij is derived. The N3 highway, designated as a motor road, crosses the bridge with 2x2 traffic lanes. On both sides of the bridge, there are separate two-way cycle paths. The bridge has a total width of 30 meters.

Immediately north of the bridge lies the Dordrecht-Centrum junction. The bridge features two bascule leaves, each approximately 15 meters long, accommodating both a roadway and a cycle path. The N3 serves as a diversion route for the transport of hazardous materials that are prohibited from passing through the Drechttunnel on the A16. The bridge is operated remotely and on request from the traffic control center in Rhoon.

## 5.2 Renovation of the bridge in 2020

The Wantijbrug was renovated in 2020. The primary reason for this renovation was the wear and tear on the two movable sections of the bridge (the bascule leaves) caused by the increased load from heavy truck traffic. Rijkswaterstaat replaced the movable bridge sections with heavier bridge decks, which required strengthening the underlying basement structure.

Additionally, the control, monitoring, and operating systems were replaced as they had reached the end of their technical lifespan.

To carry out the work, a side wall of the basement had to be partially removed, leaving the bridge insufficiently strong for heavy truck traffic at the start of the renovation. Repairs were also made to the concrete structure. The renovation work began on January 20, 2020, and the bridge was completely closed to cars, motorcycles, and trucks from January 19 to April 3, 2020. During two weekends in July 2020, the movable bridge decks were replaced, with the decks being lifted into place on July 18 and 24, 2020. The renovation of the Wantijbrug was completed on November 30, 2020.


*Figure 4. The location of the Wantij Bridge.*

### 5.3 Safety Decision-making dilemma

During the renovation of the Wantijbrug project, the client's project organization faced a complex decision-making process regarding safety, specifically concerning lifting operations with a mobile crane within the fall zone of a public road. The challenge arose from the absence of laws, regulations, and a decision-making framework within Rijkswaterstaat for mobile crane operations.

The safety measure of "completely closing the road and bridge during renovation" addressed the safety of one group: construction personnel. However, it inadvertently compromised the safety of another group; road users and road inspectors during the preparation and execution of a traffic stop. This situation is not unique and could occur in other bridge projects. It raises the question: How was this issue managed, and what recommendations can be made for handling similar safety considerations and decision-making processes in the future? This pertains to situations where no existing frameworks are available, and where multiple safety domains and target groups are involved in integral safety concerns.

Lifting operations with a mobile crane present safety risks not only for the client's and contractor's employees but also for road users—including motorists, waterway traffic, and cyclists—and bystanders. While the likelihood of failure is low, the potential consequences can be severe, including fatalities, injuries, economic damage, and reputational harm. The client, to a large extent, shares the responsibility for ensuring the safety of everyone involved.

Considering the short critical lifting periods (two 15-minute windows) and the limited time available before execution, a decision was made not to implement a full nighttime closure, which would have required extensive detours for hazardous materials and nighttime lifting operations. Instead, traffic stops during the day were chosen as the **safer and more practical option.**

*Figure 5. The road is blocked for the safety of labour and traffic users for the critical lifting periods (2 x 15 minutes); View: bridge side.*

## 5.4 Solutions for Safety dilemma

Despite the absence of specific laws and regulations, the following method is proposed as an acceptable approach for all parties when weighing safety risks across various safety domains. This approach aligns with the applicable laws, regulations, frameworks, and guidelines within Rijkswaterstaat (RWS) and is based on the risk analysis methodology used in safety science. The method consists of five steps:

1. **Organize a Safety Risk Session** with all stakeholders, including the client's project organization, contractor, Traffic Control Center, and experts, facilitated by safety advisors. During the session, the integral safety in and around the construction site is mapped out by addressing the following questions:

a. What exactly are the activities, including the duration of the operations?
b. What are the safety risks, who do they affect, and which safety domain is concerned?
c. What are the possible measures, and for whom are they effective or counterproductive?
d. For which organizations do (a), (b), and (c) have an impact, and what is required to implement them (in terms of time and budget)?

*Explanation:* In the absence of frameworks and guidelines, the foundation for financial consequences and contract adjustments is lacking, and this must be addressed promptly.

2. **Quantify and Objectify Safety Risks** (i.e., the likelihood and consequences) based on the input from step 1. This approach allows safety risks with a low probability but severe consequences to be assessed, compared, and evaluated against risks with a high probability but less severe consequences.

3. **Quantify the Impact of the Measures** identified in step 1 and 2 (in terms of both likelihood and consequences). A measure may reduce risks but could also have counterproductive effects.

4. **Compile Steps 1, 2, and 3 into a Recommendation** for the project teams of both the client and contractor. All stakeholders involved in steps 1 through 3 contribute to formulating the recommendation.

5. **Joint Decision-Making on Measures**: Based on the recommendation from step 4, the project teams of the client and contractor make a joint decision on the measures to be implemented. This approach is followed as long as no decision-making framework exists within Rijkswaterstaat for the presented issue.

*Figure 6. The road is blocked for the safety of labour and traffic users for the critical lifting periods (2 x 15 minutes)*; View: road side.

## 5.5 Safety dilemma Lifting Bridge Deck

When the bridge deck of this bascule bridge was lifted, the methodology of paragraph 5.4 was used and the road was closed off for several important safety reasons:

1. Prevent Vehicles and Pedestrians from Falling
   As the bridge deck rises, there is a gap in the roadway, which poses a serious risk of vehicles or pedestrians accidentally falling into the water or onto lower sections of the bridge.
2. Moving Machinery Hazard
   The bridge deck is a massive, heavy structure operated by powerful machinery. Any unauthorized presence near the moving parts could lead to severe accidents.
3. Counterweights and Mechanical Risks
   Many bascule bridges use counterweights that move within enclosed areas. Keeping people away prevents injuries from unexpected mechanical movements.
4. Wind and Stability Concerns
   As the bridge deck rises, strong winds could make it unstable or create dangerous conditions for pedestrians and cyclists.

5. Maritime Traffic Clearance
   The road must be clear to allow ships and boats to pass without obstruction. Delays in closing off the road could interfere with maritime operations.
6. Traffic and Operational Efficiency
   Closing the road ensures smooth operation, allowing the bridge to lift and lower efficiently without unnecessary interruptions or accidents.

Several pictures of the lifting of the bridge deck of this bascule bridge are presented in figure 7 and 8.

*Figure 7. The lifting of the bridge deck.*

*Figure 8. The lifting of the bridge deck.*

## 6 Conclusions

Based on the points discussed above, we propose the following recommendations for decision-making criteria and policy adjustments regarding integral safety, specifically:

1. Integral Safety Considerations and Decision-Making: We recommend developing a framework to address decision-making that involves multiple safety domains. Chapter 5 of this document can serve as a foundation for this framework.
2. Formulating Decision-Making Criteria: It is essential to establish clear criteria for decisions related to integral safety, particularly in cases involving lifting operations with (mobile) cranes positioned within the fall zone of public roads.
3. Alignment of Expert Advice: Expert advice should be aligned with the methodology outlined in Chapter 5, which includes safety risk sessions, quantitative risk analysis, measures analysis, recommendations to the project team, and decision-making processes.

The situation presented in this paper highlights that safety considerations and decision-making are complex and require careful attention and thorough diligence.

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