A Design Framework for a Safe Society in The Netherlands

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Abstract

Attention to integrated safety in relation to the built environment begins at the drawing board. There is little scientific research from an urban planning or architectural perspective concerning integrated safety and the built environment. This theme relates to the design of the environment, the building, and the construction site. A design framework for a safe society is needed at both the level of safety-integrated planning and safety-integrated design to address societal developments. This paper provides on one hand insights to what can be learned from safety by design in aviation and aerospace engineering, in complex systems such as tunnels and chemical installations. On the other hand, how such lessons learned can be conducted in the field of spatial planning. The paper also discuss safety by design in urban planning and the building level. The parties involved in the construction process play a crucial role in this matter. Furthermore, this paper examines how the energy transition, sustainability efforts, and climate change influence integrated safety in relation to the national spatial strategy, urban design issues, and master plans, influence new construction plans among others. But also, the impact on building safety, construction site safety, and environmental safety is described.

Keywords: Integral Safety, Education, Construction Process.

1 Introduction

Safety is important in the built environment. Where projects like public spaces, civil works or buildings in the built environment are planned, constructed, or completed, safety risks arise for users, residents, traffic participants, construction site personnel, and people present in the vicinity. This applies, for instance, to renovation activities in inner-city areas or developments along transport routes of hazardous materials. Work on, around, or within an asset during its lifecycle, such as rough or finishing construction, maintenance of installations, cleaning of building facades, or demolition of assets, initiates safety risks for stakeholders. People are present in and using the built environment, where sometimes construction activities take place.

The organization and consideration of safety during the planning, initiation, and design phases significantly influence safety during construction, usage, and demolition phases. Achieving a risk-free society is simply unrealistic, see the papers of Ale [1] and Vlek & Stallen [2]. The goal, therefore, is or should be to maintain safety risks at a socially acceptable and reasonable level. In practice, safety risks -both for individuals and large groups- can be prevented or minimized through safety measures [3], with the involved institutions fulfilling their roles accordingly. Scientifically based frameworks, decision-making processes, and transparency in roles and allocated responsibilities between organizations involved in integral safety are essential -or rather, they should be essential-for guaranteeing safety of stakeholders. This necessity becomes increasingly pronounced given the societal and demographic developments, as described in the next chapter.

Without a scientifically based and well-thought-out strategy and clear frameworks for integral safety, these societal and demographic developments will impact the safety of the built environment, and vice versa. Therefore, in the coming decades, extra attention must be given to integral safety in the construction process to create a safe vicinity / built environment, safe structures, and safe construction sites throughout their lifecycle having opportunities and threats. Given the societal and demographic challenges, attention to safety in the built environment is becoming increasingly vital.

2 Societal and Demographic Developments

2.1 Societal Developments

The societal developments influencing the safety of the built environment can broadly be divided into the following categories:

2.1.1 Urban Densification

The increasingly scarce space is being used more intensively or for multiple purposes: more people and more functions in a small area. Examples include constructing buildings next to or even above (rail)roads and stations where hazardous materials are transported. These activities heighten safety risks during the use phase of the built environment [4]. Similarly, construction in urban areas -where the environment remains in use- poses safety challenges. Urban densification, long underway in the Netherlands, offers many benefits [5]. For instance, Dutch Railways (NS) plans to build on and next to stations, small plots of land where hundreds of thousands of people pass daily. These areas combine living, working, and recreation [6]. Municipalities are also exploring ways to cover highways near and leading to their cities [7]. However, integral safety -comprising multiple safety aspects- is not always sufficiently incorporated into such studies. Even minor incidents can lead to catastrophes in densely populated areas, such as the collapse of a building due to an exploded LPG tanker. With a population density of 529 people/km² (CBS), preserving remaining "empty" spaces for recreation and focusing urban development within city contours remain critical challenges [3].

2.1.2 Energy Transition

The energy transition demands advanced systems, often integrated into existing environments and structures. These introduce new, unfamiliar safety risks for construction sites, buildings, and urban areas. Examples include replacing cables and pipelines, using electric vehicles and equipment, installing solar panels, building charging stations, adding heat pumps and underground pipelines (often near live utilities), and retrofitting buildings with insulation. Without rigorous checks on structural integrity or product certification, these efforts increase safety risks during both construction and use. Controlling these risks without clear regulations, frameworks, decision-making processes, role distribution, and accountability among stakeholders is ineffective. This applies to both urban planning and construction. Picchi *et al*. [8] demonstrated that the energy transition significantly impacts urban planning.

2.1.3 Renovation & Maintenance of assets

Beyond new construction, a significant wave of renovation and maintenance projects for real estate, infrastructure, and energy networks will profoundly affect the safety of the built environment in the Netherlands and even across Europe. The main reason hereof is that a lot of assets are built in the beginning of the 20th century or in the late ‘50. Integral safety will require greater emphasis during these processes. Over the coming decades, a large portion of structures of real estate, buildings, stations, highways, tunnels, rivers, and bridges will undergo maintenance, renovation, or replacement. Rijkswaterstaat describes this as the largest maintenance task in its history [9]. Additionally, the Council for the Living Environment and Infrastructure highlights severe foundation issues affecting approximately 425,000 buildings across urban and rural areas in the Netherlands

[10]. These must be realised in the coming decades. Renovation and maintenance projects often occur while the built environment must remain in use. Temporary closures reroute traffic, often through city centres, creating safety risks for residents, workers, and infrastructure. The lack of precise information about structures and underground utilities -often under electrical load- exacerbates these risks, compounded by unclear frameworks, decision-making processes, and responsibilities.

2.1.4 Climate Change

Climate change results in extreme weather events, including rising sea levels, stronger storms, extreme rainfall causing flooding, global warming, and urban heat accumulation. These conditions affect construction site safety, building integrity, and environmental safety, necessitating integrated planning approaches. Norman [11] explores urban planning strategies for addressing climate change, noting related safety implications, though further research is needed.

2.1.5 Major Construction Demands

The Dutch government aims to build 100,000 homes annually through 2030 to address the housing shortage [12]. This demand indirectly relates to workforce and capacity shortages, as many skilled workers are already engaged in ongoing projects. As a result, labour is often sourced internationally, creating safety challenges during construction. The Arbovisie 2040 report [13] highlights these issues.

These societal developments increase safety risks for various stakeholders -residents, traffic participants, construction workers, and passersby- during both construction and use phases. Therefore, prioritizing integral safety within construction processes is essential to mitigate these risks effectively.

2.2 Demographic Developments

Demographic changes have implicit effects on the safety of the built environment. These can be categorized as follows:

2.2.1 Aging Population

Knowledge retention within organizations is a significant challenge [14]. As the workforce ages, vast amounts of expertise can suddenly become unavailable unless it is systematically captured and passed on to the next generation of professionals. Organizations must proactively address this issue to ensure continuity.

2.2.2 Chronic Shortage of Skilled Personnel

Skilled workers on construction sites are scarce and often committed to long-term projects. This creates a structural shortage of qualified personnel in the long run [15]. National-level strategic planning and decision-making could help address this issue, but it raises the question of who bears the responsibility within or outside the construction sector.

2.2.3 Use of Migrant Workers

Labour shortages are often addressed by employing non-Dutch-speaking workers. The construction of the Corbulo Tunnel revealed the challenges of managing projects with multiple nationalities involved [16]. Long supplier chains, language and cultural differences pose significant barriers, directly affecting safety during construction. While construction companies increasingly rely on non-Dutch-speaking migrant workers, they remain responsible for the safety of all employees, including subcontracted labour. This issue predominantly affects large construction firms. National policies or strategies on responsibilities in safety management could offer a solution.

2.2.4 Rise of Solo Enterprises

The construction sector is seeing a rise in small, specialized self-employed businesses (ZZP'ers). According to the Economic Institute for Construction, over 175,000 self-employed workers operate in the Dutch construction sector [17]. This trend alters contractual relationships between construction companies and these one-person businesses, compared to traditional employer-employee agreements. The impact on supply chain safety collaboration remains largely unexplored.

However, an increase in stakeholders necessitates stronger safety coordination.

2.3 Developments impact on safety

These developments place societal acceptance and tolerance of risks under pressure. Several (near) accidents have strongly demonstrated this. Examples include the Enschede fireworks disaster (2000), the balcony collapses in Maastricht (2003), the Volendam café fire (2005), accidents involving bridge operations, building collapses due to structural errors or earthquakes in Groningen (2005–present), the Voorschoten train disaster (2023), the crane accident in Lochem (2024), collapsed ramps at the Sint Antonius Hospital parking garage in Nieuwegein (2024), and frequent near-misses involving hazardous materials or neglected housing maintenance. These incidents have sharply raised public awareness regarding safety. In many cases, these events have caused societal disruption and political outrage, leading citizens to closely scrutinize the government. This often results in the government intensifying efforts to enforce existing regulations or introduce new rules and policy guidelines, as noted by Ale [3]. Following significant incidents, investigations are typically carried out by the Dutch Safety Board, the Netherlands Labour Authority, or, in cases of "safety crimes," by the Public Prosecution Service to determine the cause and to learn from the event.

The question arises as to whether this approach is scientifically effective and whether it truly ensures that risks remain manageable, acceptable, and tolerable, as discussed by [18,19]. Is it the frameworks, decision making processes, role distribution, and responsibilities between involved organizations that lead to financially backed agreements on safety measures to prevent accidents, or are there other factors -such as sector specific agreements- that play a role? Moreover, encouraging common sense and engaging top level expertise in the field of intensive and multifunctional land use related to safety is not an unnecessary luxury.

3 Laws and Regulations on Integral Safety

The 'right to be safe' was originally enshrined as a general principle in the Dutch constitution of 1798, when the French brought the freedoms of the French Revolution to the country, stating: 'The security of the person, life, honour, and property.' However, this provision was later removed. Despite the absence of a specific "right to safety" in the current Dutch Constitution, the government still provides a certain degree of protection for its population against safety risks. For instance, risks related to flooding, hazardous substances in the living environment [20], or risks faced by employees or users of public infrastructure. E.g. the Dutch Tunnel Act ensures tunnel users are provided with an acceptable level of safety by imposing measures in, on, or around tunnels [21].

Furthermore, ministerial regulations are regularly issued to offer protection to the public. For example, the Regulation Stimulating Road Safety Measures 2022-2023 guarantees road users a certain level of safety by requiring mandatory safety measures along or near roads. In buildings, standards -such as the Eurocodes- ensure structural safety, providing building occupants with a certain level of security [22,23]. Additionally, in the EU Directive 92/57/EEC [24], minimum safety and health requirements for temporary and mobile construction sites are described. These laws are created in both the social and physical domains to protect people from risks, although achieving 100% safety is neither possible nor easily realizable, as discussed by [1,2].

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).
- 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 above enumeration provides an interesting insight into how safety-related laws and regulations are organized within distinct safety domains. As one may observe, these regulations regarding integral safety are not integrally approached (i.e., not sectoral and not focused on aspects such as geographical grounds, the lifecycle of a building, or the construction process). Though the introduction of the new Environmental Planning Act 2024 has promoted more interaction between safety domains, there is still no integral or holistic approach to safety across all domains, which is the key to integral safety. How chain collaboration in this area functions is also a gap in knowledge. This is particularly relevant for understanding how integral safety works in the construction process.

Moreover, the law is often a reaction to situations where things have gone wrong. 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. 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.

4 A Macro, Meso and Micro approach

4.1 Scientific research and education

Currently, no scientific research is being conducted on integral safety in the construction process or the built environment, even though this scientific field is in its infancy, with every program or project in construction dealing with it [4]. Furthermore, it should be noticed that integral safety is currently not part of the Civil Engineering and Architecture curricula at technical universities Despite the existing laws and regulations for various safety domains, agreements at the national level, frameworks and certifications within companies, efforts by safety advisors, clients, contractors, authorities, and other stakeholders, and apart from societal or demographic developments, there is a lack of a coherent approach -based on applied scientific grounds- for integral safety from a scientific perspective at various scales [25,26], with its own issues:

1. Macro-level
   National / regional / city level: national, provincial, regional, or municipal level;
2. Meso-level
   Neighbourhood level: layout of a neighbourhood / urban design, district;
3. Micro-level
   Building or project level: individual construction or renovation of an object.

4.2 Challenges

4.2.1 Macro level

- Despite existing laws, regulations, competent authorities, and national agreements, many accidents still occur.

- In road safety, there are more than 700 fatal victims per year [27].
- According to The Occupational Accidents Monitor 2023 and 2024 of The Netherlands Labour Authority [28,29], the construction sector ranks among the top three sectors where relatively many work accidents occur.
- In construction, there are an average of about 411 reportable accidents with (permanent) injuries, or about 118 cases per 100,000 jobs. With these figures, construction remains one of the sectors with the most accidents.
- In planning related to the transport of hazardous substances (external safety), dangerous situations and multiple accidents have occurred despite existing laws and regulations. Nevertheless, national developments continue to occur where stations are being planned along or above these sites.
- Various research reports from the Dutch Safety Board [30,31] recommend that responsibility is often not adequately taken.
- Laws and regulations for safety domains (e.g., road safety and employee safety) are sometimes contradictory, and bottlenecks are often discovered late in the process—at the design stage or even during the execution of a project. Integral safety covers several safety domains: social and physical, which can be further subdivided into different safety themes. Safety is a multidimensional and multidisciplinary concept [32].
- Laws and regulations are not sufficiently tailored to societal and technological developments -such as the energy transition, housing shortages, and building within urban boundaries- where new and often unknown risks are introduced to new target groups.
- Since safety is organized across multiple ministries and encompasses several safety domains, the chain collaboration and its translation at the meso- and micro-level is not always optimal, leading to unsafe situations in practice, as described by Van Marrewijk & van der Steen [33].
- Van Marrewijk & van der Steen [33] have described that organizations in the construction sector can learn from fatal accidents through the interplay of processes on legal, ethical, and operational levels. There is still much to be gained in this area. The learning capacity in the construction sector can be improved, see, for example [33].

4.2.2 Meso level

- Insufficient attention to financing and budgeting for safety in urban planning developments during the conceptual phase (i.e., initiative and planning phase) often leads to situations that are no longer changeable during the design phase. This is also applicable to renovation, maintenance, and management projects, where the geographical boundaries and footprints are often already set. The same holds true for the implementation and operational phases. Due to insufficient or lack of budgeting for safety at the meso-level, safety measures are constantly under pressure during the design and execution stages. Safety is not always explicitly considered, nor are the associated costs and benefits. This presents a challenge for clients, owners, and managers of assets, such as civil works, public spaces, and buildings.

- Fragmentation and dispersion of responsibility for safety leads to complex issues in practice when initiating projects following the decision-making framework for infrastructure projects or urban planning. Who is responsible for safety at each stage of the construction process and within the built environment?
- A decision-making framework and management mechanisms for integral safety in the chain are lacking. E.g. the responsibility for external safety or occupational safety is incorporated into legislation. However, an integral safety decision-making approach or framework that encompasses different safety domains is lacking and often not addressed, let alone are the decisions are made explicitly made in the decision-making process where integral safety should be a central decision-making consideration and roles regarding safety are appointed. Additionally, a check/control mechanism is almost non-existent.
- A lack of collaboration, coordination, and information exchange between stakeholders, as well as a failure to document these processes between different parties and levels within the chain collaboration, often results in flawed or non-transparent decision-making where safety is not a standard consideration.
- Although safe maintenance is anchored in regulations such as the Dutch Building Decree (Bouwbesluit) and the Occupational Health and Safety Act (Arbowet), safety is often not viewed as a design variable by architects involved in urban and architectural developments. Once the building is constructed, it becomes more difficult and expensive to implement safety measures. Integrating safety measures within masterplans and urban designs -i.e., from the early beginning of the construction process- yields safety benefits and reduces the need for additional safety measures at the building level.

4.2.3 Micro level

- In the interplay between the organizational structure of the client, contractor, owner, manager, environment, competent authorities, designer, user, and other stakeholders, safety is often a point of discussion.
- Clients have transferred risks to market parties (engineering firms or contractors) and have recently operated under the "market unless" principle. Small margins, a saturated market with intense competition, and high material and equipment prices are factors. Since the COVID-19 pandemic, the budgets of market parties have been under pressure, with more focus on the costs and benefits of safety measures.
- Practical examples of integrated safety arise in various projects and developments; however, the same issues are reinvented for each project. The learning capacity between projects is still in its infancy.
- Responsibilities, roles, tasks, and mandates are not standardized, resulting in organizations defining them on their own. This is also the case with complying with legal obligations, which is inefficient.
- Large contractors have become management organizations that work with many subcontractors and suppliers. Oversight on safety at the subcontractor level is not always visible, nor are certifications always available for these companies.
- SMEs (small and medium-sized enterprises) do not have safety expertise required to carry out complex tasks. These companies are often unaware of the safety risks associated with their work. Several recent examples of fatal accidents, such as when installing solar panels on rooftops or electrocutions during electrical

connections, show that SMEs are not aware of safety.

- Safety concepts are not universally defined and are interpreted differently by stakeholders and/or are not considered by organizations, leading to varying perceptions of safety, in case of external safety. In environmental legislation, external safety refers to the search for optimal use and division of limited space near usage, production, storage locations, and the transport of hazardous substances. Wind turbines also fall under this definition. In the context of the sector Safety Program in Construction 2024, environmental safety refers to the safety of people (or buildings) in the vicinity of a construction site. The same terminology, but with different scopes and regulations, involving various consultants.
- The hiring of non-Dutch speaking personnel - due to staffing shortages-often leads to unsafe situations during realisation. Knowledge and culture also play a role in safety awareness and handling safety during the construction.
- Attitude and behaviour, and ownership by (higher) management largely determine the corporate culture, of which safety is a part, and how safety is handled on the work floor.
- In statements by management, safety is almost always prioritized over money. However, in practice, there are situations where money takes precedence over safety, and clients must be willing to pay extra for safety measures. This applies to both large companies and SMEs working for consumers.
- Certifications such as VCA*, VCA**, and NEN-Safety Culture Ladder (SCL) are used by organizations to improve the safety culture on the work floor. This is often done at the higher management (strategic) level. Implementation and translation to project organizations at the operational level need more attention. Attitude, behaviour, and corporate culture play a crucial role in this process.
- Designing with safety in mind is still in its infancy. Many hazardous situations during the construction, use or maintenance phase, occurs, which could be eliminated during the design phase. The reality, however, is that civil engineers and architects are not trained for this. Designing with safety for safe objects and a safe environment is unfamiliar territory for designers, often because clear frameworks and guidelines are lacking.

5 Conclusions and recommendations

When analysing the above situation, it becomes clear that the safety of the vicinity, object safety, and construction site safety are often treated separately in terms of legislation, policy, responsibilities, processes, designs, and tools. However, these aspects of safety are inextricably linked with each other. This exactly the meaning of integral safety, where the safety of the entire construction environment must be ensured, both during the construction phase and after the completion of the asset. It is therefore recommended that an integral approach of all the safety domains should be considered.

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