The Communication of Vision Zero Values in Tunnel Safety Management

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ABSTRACT: The Norwegian Public Roads Administration implemented the concept of Vision Zero in 1999. This is a vision of a road transport system that is safe for humans even if an accident occurs, also in the event of a tunnel fire. However, during the recent years, several tunnel fire incidents in Norway have demonstrated the potential for major accidents. In this paper, we discuss how tunnel safety designs are communicated by national agencies with governmental tasks. Our perspective is systems safety theory applied to Vision Zero principles. Even if the Vision Zero has been a political desired concept in Norway for almost twenty years, the Vision Zero is still inadequately communicated through the hierarchical levels. The lack of constraints is preventing the Vision Zero from being conceptualised and implemented, which may cause differences in the understanding of Vision Zero between the hierarchical levels in the tunnel system safety management.

Keywords: Vision Zero, systems safety, tunnel safety management, constraints, communication, values.

1. Introduction

The Norwegian National Transportation Plan 2018-2029 (The Norwegian Ministry of Transport and Communication, 2017) gives an ambitious prospect on the Norwegian road network the coming years. The main goal is to meet the growing transportation needs of most people and the business community by building a transport network in line with the future and maintaining the quality on existing infrastructure. Safety is an essential element in this plan.

To meet the needs of an effective transport system in the varied Norwegian topography, Norway has an increasing number of long and complicated road tunnel designs. Today the Norwegian road infrastructure consists of more than 1130 tunnels. Among these, there are 34 subsea tunnels and 24 mountain tunnels with steep slopes (> 5%). Such tunnels comprises only 5% of the length of the Norwegian road tunnels (Nævestad et al., 2016), but are overrepresented regarding vehicle fires. Steep slopes increases the danger of fire, especially in heavy goods vehicles.

Previous tunnel fire incidents in Norway and Europe have demonstrated the potential for major accidents. Since 1996, more than 70 people have lost their lives due to fires in European tunnels. Several serious tunnel fires in Norway (AIBN, 2018, 2017, 2016a, 2016b, 2015, 2013) have led to heavy criticism towards tunnel safety management (Office of the Auditor General, 2016; Road Supervisory Authority of Norway, 2018). So far, no lives are lost in the fires and subsequent smoke exposure in Norwegian tunnels, but inhalation of toxic gases have caused serious injuries among a high number of people being involved in such incidents. Due to dense smoke and emergency exits far away, road-users experienced life-threatening issues (Njå and Kuran, 2014).

The Norwegian Public Roads Administration (NPRA) adopted the concept of Vision Zero in 1999 (Langeland, 2009), stating that nobody shall be killed or seriously injured in the road traffic. Since then the number of fatalities and severe injuries in road traffic has been significantly reduced. In the year 2000, the number of fatalities and severe injuries was 1593, by 2016 this was reduced to 791 (The Norwegian Ministry of Transport and Communication, 2017). To set further speed towards Vision Zero, The National Transport Plan 2018-2029, sets out an interim target with the ambition to reduce the number of fatalities and serious injuries in road traffic to a maximum of 350 by 2030. According to The Norwegian Ministry of Transport and Communication (2016), a well-functioning cross-sectoral cooperation is becoming increasingly important as the number of fatalities and injured in road traffic decreases and the effect of the simplest remedies has been harvested.

In the event of a tunnel fire, self-rescue is the authorities' expectations for the evacuation

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behaviour. This means that people, affected by a tunnel fire, must evacuate the tunnel by themselves – they cannot rely on rescue. Peoples' survivability in a tunnel fire thus depends on how far they are from the exits, their health, condition and endurance, their tolerance of toxic gases, or simply lucky circumstances. Consequently, we claim that in such situations, the Authorities' expectations of self-rescue is not in accordance with the Vision Zero.

We consider road tunnels as complex socio-technical systems, a concept that reflects central issues within resilience (Rampp et al., 2019). Such systems are characterised by stakeholders from dissimilar fields of knowledge and disciplines, which have different approaches to risk. Thus, there are variation in the conception on how to act on Vision Zero.

In this paper, we discuss how Vision Zero values are communicated in the tunnel safety management. Our perspective is systems safety theory (Leveson, 2011) applied to the Vision Zero principles. We claim that Vision Zero must be consciously followed-up using practical constraints if it shall be effective. If not, the efforts to improve traffic safety will be loosely coupled to the Vision Zero and the actors further down in the system hierarchy will have unlimited interpretational liberty regarding the Vision Zero.

2. The Vision Zero as a Road Philosophy

The process of Vision Zero started in Sweden in 1997 (Lindberg, 2002). In Norway, the Vision Zero was embraced by the politicians and incorporated in the National Transport Plan 2002-2011 (The Norwegian Ministry of Transport and Communication, 2000). Since then, the Vision Zero has become a concept with increasing importance in the contemporary safety debate (Langeland, 2009), symbolising a change in policy from a continuous decrease in number of fatalities and injuries to a vision of zero fatalities and permanent injuries. The rationale for Vision Zero was underpinned by deep ethical questions concerning an acceptable level of safety and the price decision-makers and society were willing to pay for it. Elvik (1999) had a critical stance from the start and according to his predictions then, we are now at lowest possible level of people killed in traffic. We do not think this worldview exists today.

The Vision Zero is rooted in three pillars: ethical principle, scientific based knowledge, and shared responsibility.

2.1 *Vision Zero as an ethical principle*

By the Vision Zero, the claim of protecting human life and health becomes close to absolute. In an ethical perspective, this implies a shift from the utilitarian principle to normative ethics, which is not based on the consequences of a decision, but on the fundamental view of what is right and wrong when it comes to human life and health. According to Tingvall and Lie (2001), this change of ethical perspective represents an adaptation to what is prevalent in society in general, and not an isolated change in the road transport system.

Belin et al. (2012) claim that the Swedish government did not discount the fact that other sub-systems also have a role to play. The purposes of which are to support and help road users – such as regulations, training, information, monitoring, rescue services, care and rehabilitation – should therefore be designed and structured so that they contribute towards safe road traffic in an effective way. It was argued that the design and structure of the road transport system should be adapted to the requirements that follow from Vision Zero. The physical pre-requisites of human beings for withstanding road accidents should be the normative requirements in designing and structuring the road transport system.

The ethical principle are associated with central risk management issues, which includes the principles known as Reducing Risks, Protecting People (R2P2) (HSE, 2001). Changes in the preferences, values and expectations of society, increases the need for the meaning of risk to encompass more than physical harm by taking into account other factors such as ethical, economic and social considerations.

Related to tunnel safety, the ethical principle of Vision Zero has implications on both the design and operation of the tunnels. The system design must acknowledge and be sufficient robust to meet specific demands when accidents occur. Consequently, in the event of a tunnel fire, the ethical principle stresses the importance of protecting humans' lives and health.

2.2 *Vision Zero as scientific based knowledge*

To design a system that is safe for humans even if an accident occurs, Tingvall and Lie (2001) emphasize the human biological tolerance as a critical limit in the system design. They claim that such critical safety limits means a simplification in planning and designing the future road transport system. Additionally, this approach gives an opportunity to define what is safe already from the start.

Related to tunnels, the critical safety limits should relate to the hazards that the activity in the tunnels may cause. Even if designers and tunnel operators would like the activity in tunnels to be kept below an acceptable level of risk, the level of what is acceptable is not easy to decide. When striving for a risk-level as low as reasonable practicable, known as the ALARP-principle (Aven, 2006), decision-making processes that

generates alternatives, cost-effectiveness and management involvement are thus desired. Aven et al. (2003) claim that there does not exist any given goals regarding risk acceptance in society. Neither does an objective method for analysing risk. The choice of risk level are dependent on the alternatives, the values, and the opinions.

Following Tingvall and Lie, the human biological tolerance must be a critical limit in the system design when it comes to tunnel safety. Thus, the design of the system must protect the life and health of the most vulnerable humans, like children, old, sick and disabled people. This implies that during the event of a tunnel fire, the system must safeguard all the people involved, even the most vulnerable, from death or permanent injuries caused by the fire. In order to recognize the knowledge principle of the Vision Zero we expect to find system requirement and constraints supporting knowledge generation for tunnels.

2.3 *Vision Zero as shared responsibility*

A traditional perspective of responsibility builds upon how the individuals use the road transport system. The system is open for everyone at his or her own risk, and the responsibility for traffic accidents has traditionally been ascribed to the road users. In contrast, Tingvall and Lie (2001) claim that the Vision Zero are changing this view of responsibility. The individuals are responsible for complying with laws and regulations, while the system designer is responsible to build safety into the system.

The term 'system designer' is not fully clear, but is referring to all players who, in their professional work, in some way influence the design and function of the road transport system (Beling, et al., 2012). In principle, shared responsibility is based on the consideration of that the system designers always should have ultimate responsibility for the design, maintenance and use of the road transport system. In that way the system designers is responsible for the safety level of the entire system. However, the road users are responsible for showing consideration, for having a sense of judgment and responsibility in traffic, and for complying with traffic regulations. If the road users does not bear their share of responsibility, due to for example a lack of knowledge, acceptance or ability, or if injuries occur, the system designers must take further measures to the extent necessary to combat the occurrence of deaths or serious injuries.

According to Langeland (2009), the shared responsibility between the road users and the system designers referred to be one of the cornerstones of the Vision Zero. After the devastating terror events of July 22nd 2011, the cooperation principle was introduced to improve the work within societal safety. The cooperation principle means that authorities, enterprises or agencies have an independent responsibility to ensure the best possible interaction with relevant actors and businesses in the work on prevention, emergency preparedness and crisis management. The principle is embedded in the instructions for the ministries' work on societal safety (societal safety instructions) (The Norwegian Ministry of Justice and Public Security, 2017), and is closely related to the Vision Zero as shared responsibility.

Related to tunnel safety, the shared responsibility principle calls for cooperation and interaction between many stakeholders to find innovative solutions to difficult problems. Belin et al. (2012) suggest posing the question "What must be done in order to create a safe road transport system?" to highlight the importance of pursuing alternative and innovative road safety policies.

3. Systems Thinking Applied to Tunnel Safety

Different stakeholders' perspectives and their judgments of the tunnel safety levels may influence the adaptions to the Vision Zero, and some will probably argue that the Vision Zero is a utopian concept.

According to Hollnagel and Speziali (2008), several methods have been developed since the 1990s in the context of risk and safety assessment. They refer to STAMP and FRAM as methods suitable for systems that are tightly coupled and intractable. FRAM is a method for accident investigation as well as risk assessment, while in STAMP, systems theory is regarded as useful to analyse accidents, particularly system accidents. STAMP highly emphasise a control structure that will enforce the necessary constraints in order to prevent future accidents.

The scope of the Vision Zero is to prevent future accidents. Thus, systems safety engineering based on STAMP, is in this context found useful as an approach to understand how safety can be designed into the system.

3.1 *Safety in complex sociotechnical systems*

According to Leveson (2011), complexity comes in many forms, and increases in the systems we are building. Interactive complexity is related to the interaction among system components. Related to tunnels, this could be the interaction between humans, technology and organization. For example, in the event of a tunnel fire – how can the prescribed procedures on the tunnel ventilation cause any harm to humans? Dynamic complexity is related to changes over time. During a tunnel's lifetime, there may be changes related to both humans, technology and organizations. For example, based on the

knowledge we have today, would we claim that the long single tube tunnels are safe enough in the event of a tunnel fire?

During crises, High Reliability Organizations migrate the decision-making to frontline workers. According to Leveson, however, a problem is that the assumption that frontline workers will have the necessary knowledge and judgment to make decisions is not necessarily true. Related to the authorities' expectations of self-rescue in the event of a tunnel fire, the road users may have inadequate information and understanding of the situation. This may cause the road users to make wrong decisions. Necessary constraints to combat fire hazards in tunnels are not developed and used as design premises for Norwegian tunnels.

Another problem is the authorities' assumption of road users' knowledge of the self-rescue principle, and road users' ability to escape from a tunnel fire. The fire departments contingency plans may even be inexpedient in such a situation, especially when it comes to initial effort and the direction of the ventilation. Thus, in the event of a tunnel fire the road users must be safeguarded in some other way.

Leveson emphasizes that change is characteristic for all systems. Physical equipment deteriorates and degrades. Human behaviour, values and priorities changes. Organizations evolve. Thus, the safety control structure itself will change. Changes may also occur in the physical and social environment, in which the system operates and interacts. To be effective, Leveson claims that controls need to be designed in order to meet risk associated with all these types of changes. We need systems and safety thinking more concerned with adaption and critical assessment than compliance based safety.

3.2 *Sociotechnical control*

Leveson claims that the system safety approach assumes that some properties of systems can be treated adequately only in their entirety, taking into account all facets relating the social and the technical aspects.

In line with Leveson, the tunnel safety management system can be regarded as a hierarchical structure. As the Vision Zero is a political desired concept, we have chosen to focus on the top hierarchical levels. By Levesons perspective on systems safety, we are interested in how each level of the national agencies with governmental tasks imposes constraints related to the vision on the level beneath it. In this sense, constraints or lack of constraints for example at the level of Ministry of Transport and Communication allow or control the behaviour of Norwegian Public Roads Administration/ Norwegian Directorate of Public Roads. One important task related to The Ministry of Transport and Communication is to implement and control the political decided concept of Vision Zero. The Norwegian Directorate of Public Roads is a nationwide governmental body with regional offices, with a professional role in developing, managing and communicate knowledge within its field. Through the professional work, the task is to relieve the ministry and to implement measures.

To control the processes at lower levels in the hierarchy, Leveson claim there must be control processes operating between the levels. The control processes is responsible to enforce the safety constraints. For example, by the Handbook N500, Norwegian Public Roads Administration/Norwegian Directorate of Public Roads communicate constraints related to the design of tunnels. If the handbook inadequately communicates the knowledge of hazards related to steep slopes single tube tunnels, or if safety constraints related to Vision Zero values is violated, the probability of a major tunnel fire incident is present.

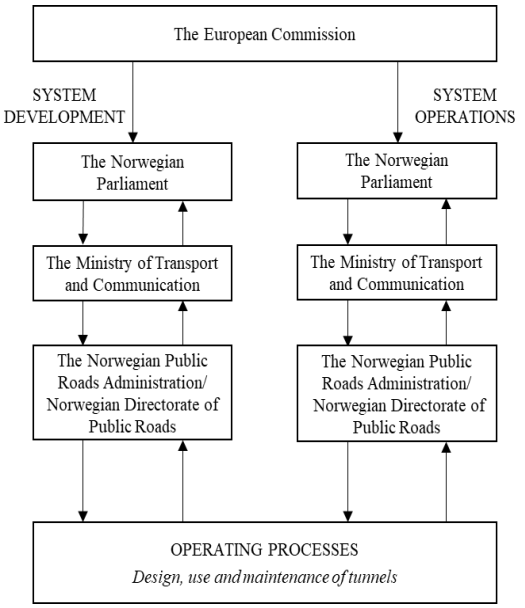

Figure 1: A simplified model of the sociotechnical hierarchical safety control structure of the Norwegian tunnel system (based on Leveson, 2011).

4. The Communication of Vision Zero Values in a Hierarchical Perspective on Tunnel Safety Management

This section assesses how tunnel safety designs are communicated by national agencies with governmental tasks. The perspective of this assessment is based on systems safety theory applied to Vision Zero principles. We start with the EU directive even though the Vision Zero

principle is not explicitly expressed as a political stance for road tunnels. The EU directive is an important norm for the Norwegian regulations.

4.1 *The European Commission*

The disastrous events in Europe around 15-20 years ago resulted in the EU Directive 2004/54/EC. The Directive sets minimum safety requirements for tunnels in the Trans-European Road Network.

Although Norway do not have a full membership in the European Union, Norway is linked to the Trans-European road network. Thus, Norway is strongly influenced by the EU policy.

Annex I provides a basis for deciding on safety measures, for example expressing that safety measures "*…shall be based on a systematic consideration of all aspects of the system composed of the infrastructure, operation, users and vehicles"* (Annex I; 1.1.1).

Annex II is about approval of the design, safety documentation, commissioning of a tunnel, modifications and periodic exercises. Regarding approval of the design, several agencies are involved in the safety documentation process, before any construction work begins. This shall be a cooperation between the Tunnel Manager, the Safety Officer, the Inspection Entity and the Administrative Authority. "*The Tunnel Manager shall compile safety documentation for each tunnel and keep it permanently up-to date"* (Annex II; 2.1.). The safety documentation shall *"describe the preventive and safeguard measures needed to ensure the safety of users, taking into account people with reduced mobility and disabled people, the nature of the route…"* (Annex II; 2.2).

4.2 *The Norwegian Parliament*

The idea of the Vision Zero was embraced by the parliament and incorporated for the first time in the National Transport Plan 2002-2011 (The Norwegian Ministry of Transport and Communication, 2000). In this plan, the ethical principle is acknowledged; "*In the long-term work with safety in the transport sector, the Government lays down a vision saying there should be no accidents that result in death or permanent injuries*" (p. 3). The transport plan claims that this requires effort in all parts of the transport system, but place its main emphasis on the road transport sector, containing over 90 per cent of the accident fatalities. The principles of shared responsibility and scientific based knowledge is highlighted by recognizing that the *"Reduction in the number of injured and killed requires interaction between a number of road safety measures, both physical measures on the road network, behavioural measures, control and sanctions, training, information and knowledge building*" (p. 3).

In The National Transport Plan 2018-2029 (The Norwegian Ministry of Transport and Communication, 2017), the Vision Zero principles is highly recognised by the statement "*The Government's main goal for transport safety is to reduce transport accidents in line with the Vision Zero"* (p. 14).

The ethical principle of Vision Zero is emphasised by "*The main goal involves a vision that there should not be accidents with killed or severely injured in the transport sector"* (p. 14). This goal is operationalized by stating "*By 2030, the number of killed and severely injured in road traffic will be reduced to a maximum of 350" (p. 14)*.

The scientific based knowledge principle in Vision Zero is acknowledged by an optimistic view on science in the statement "*The development of society and technological advances during the planning period and beyond 2030 will have a major impact on transport safety"* (p. 14). The Government's efforts to reduce the number of fatalities and severed injured in traffic, shall be based on risk assessments. In order to reach the milestone target of a maximum of 350 killed and severely injured in road traffic by 2030, the Government will direct its efforts towards five main focus areas: safe roads, risk behaviour in traffic, especially vulnerable groups in traffic, technology and heavy vehicles.

The third tenet of the Vision Zero, shared responsibility, is emphasised by stating that the "*Meld. St. 40 (2015-2016) Traffic safety work - coordination and organization, will be followed up during the period of this plan"* (p.15). The main object of Meld. St. 40 (2015-2016) is to emphasise the importance of coordination at the overall level and cross-sectoral challenges in traffic safety work. The Government agrees upon the need for strong coordination of the effort, so that the right and most effective measures can be selected and carried out, and thus provide an increased road safety for the road users (The Norwegian Ministry of Transport and Communication, 2016).

However, even if the Vision Zero is communicated as a desired concept in The National Transport Plan 2018-2029, we cannot see any signs of constraints related to tunnels that are imposed or communicated to the Ministry of Transport and Communication.

4.3 *The Ministry of Transport and Communication*

In Norway, the EU Directive 2004/54/EC is implemented in the Regulation of Minimum Safety Requirements of Certain Road Tunnels

(The Norwegian Ministry of Transport and Communication, 2007).

By the regulation, The Norwegian Directorate of Public Roads, is pointed out as the main Administrative Authority. Thus, the directorate have the responsibility to ensure that all aspects of safety in tunnels are assured, and that they take the necessary steps to ensure compliance with the regulation.

Regarding the State budget 2019, the Norwegian Public Roads Administration has received an allocation letter from The Ministry of Transport and Communication (2019). The allocation letter applies to the Parliaments decision and the goals, priorities and reporting requirements that the Ministry of Transportation and Communication makes to the Norwegian Public Roads Administration in 2019. The letter points at the overall objective of transport policy, which entails "*... a transport system that is safe, promote value creation and contributes to the low-emission society"* (p. 2).

Through the allocation letter, the Ministry of Transport and Communication expects the Norwegian Public Roads Administration to prioritize on the main goals and the guidelines set by the National Transport Plan 2018-2029 and the allocation letter. As previously mentioned, one of these goals is "*…to reduce transport accidents in line with the Vision Zero" (p.14)*. Further, the allocation letter states that "*... measures preventing the most serious accidents and types of accidents must be prioritized"* (p. 8).

The allocation letter states that the overriding guiding principles in governmental management are based on goals and performance management, and that the risk assessment should be integrated in this. Good risk assessments are emphasised as important in the management dialogue, and proper use may help to focus on what is important. The work on societal safety must be measurable, systematic and traceable and be an integrated part of the activities. In other words, the Ministry of Transport and Communication require a form of constraints, but do not impose or communicate specific and measurable constraints related to tunnels.

4.4 *The Norwegian Public Roads Administration/ Norwegian Directorate of Public Roads*

The Handbook N500 (The Norwegian Directorate of Public Roads, 2016) comprises issues related to designing and engineering tunnels, and describes general safety measures in compliance with minimum safety requirements in the Regulation of Minimum Safety Requirements of Certain Road Tunnels.

According to the handbook, designing and engineering tunnels should be based on dimensional time of use, uptime calculations, vulnerability and safety assessments, as well as conditions related to operation and maintenance.

The Handbook N500 describes the provisions given by the Regulation of Minimum Safety Requirements of Certain Road Tunnels for carrying out risk analysis, it clarifies existing principles regarding tunnel safety, and gives instructions concerning emergency preparedness analysis and emergency preparedness planning.

In the event of a tunnel fire, or another incident, the Handbook N500 emphasises "*the principle of self-rescue"* (p. 26). That is, the road users themselves must get out of the tunnel, either on foot or by the means of a vehicle.

Regarding safety measures and safety equipment, the requirements are based on the different classifications of the tunnels. The classifications are grounded on annual day traffic and the length of the tunnel, and sets the requirements of safety measures and safety equipment.

In general, the Handbook N500 can be regarded as an operationalization of the safety management principles of Vision Zero. However, the vision is not mentioned by its name, neither its principles. The N500 requirements, risk assessments, emergency preparedness analysis practices and the development of solutions are much more compliance-based, compared to the function based Vision Zero philosophy. This may be a result of lack of safety constraints given by the levels above (The Norwegian Parliament and The Norwegian Ministry of Transport and Communication), or too much freedom to interpret their intentions regarding tunnel safety.

5. Discussion

A tunnel fire may be a result from inadequate control or enforcement of safety constraints related to the Vision Zero values. Our analyses of the safety control structure of the Norwegian tunnel system shows a lack of constraints imposed by the top hierarchical levels. This may be caused by the fact that Vision Zero has not been conceptualized and implemented through all system levels. This is supported by Langeland (2009), who claims that the Vision Zero has not been conceptualised, instantiated or made ready for action by the key actors. Constraints related to Vision Zero is not provided in Handbook N500, and we thus find that the vision is inadequately communicated.

The concept of Vision Zero emphasises that we have to focus on the most serious accidents. A concept is conceptualised when it is defined and instantiated, when the concept is given more specific meaning. Thus, there might be agreement among the actors about the concept but not about how it should be conceptualised. To conceptualise

the Vision Zero, scientific based knowledge must be used to develop safety measures and safety constraints. This is a shared responsibility among stakeholders through all the hierarchical levels. Thus, the Vision Zero values *scientific based knowledge* and *shared responsibility* are recognised as important when developing constraints related to tunnel safety.

In a hierarchical perspective on tunnel safety, the Vision Zero has the potential to influence the tunnel safety work on each level. It can be expressed in a detailed and specific way, for example, "no human shall be trapped in the smoke from a tunnel fire", "no human shall be exposed for high temperatures during a tunnel fire", "information shall be provided in the event of a tunnel fire". Leveson (2011) highlight the importance of effective communication channels to provide necessary information to impose the safety constraints and feedback about how effectively the constraints are being satisfied. Feedback is critical to provide adaptive control in order to safeguard the system.

Leveson claim that the first step in any safety effort involves agreeing on the types of accidents or losses to be considered. In this context, the Vision Zero means that there should not be traffic accidents with people being killed or seriously injured, nor in the event of a tunnel fire. Thus, an accident definition used in the design of a tunnel can be formulated as:

A1. A major tunnel fire may cause people to be killed or seriously injured.

A useful way of to define the boundaries of a system is to draw them to include the conditions related to the accident over which the system designer has some control. If designers are expected to create systems that eliminate or control hazards and thus prevent accidents, then those hazards must be in their design space. This control requirement is the reason for distinguishing between the terms accident and hazard.

If using our definition of an accident (A1), hazards associated with a tunnel fire in steep slopes single tube tunnels might be defined as:

H1. Heavy goods vehicles loaded with flammable or explosive goods.
H2. Overheated brakes and/or motor in heavy goods vehicles.
H3. Fire or explosion in heavy goods vehicle.
H4. Dense smoke and toxic gasses.
H5. Ventilation spreading smoke and toxic gasses towards people inside the tunnel.
H6. Long distance to exits.
H7. Lack of information to the people inside the tunnel.
H8. Rough uneven surface on tunnel walls.

After the hazards are identified, the next step is to specify the system-level safety requirements and design constraints necessary to prevent the hazards from occurring. According to Leveson, these constraints will be used to guide the system design and tradeoff analyses. Constraints for the hazards H4 and H5, based on experiences from previous accidents, Vision Zero values and Njå (2016), might be:

C1. People must not be killed or seriously injured by the smoke and toxic gasses (H4).
C2. A critical limit to human biological tolerance must be set at a level where the weakest individuals do not risk having a permanent injury (H4).
C3. The ventilation must not cause people to be trapped in smoke and toxic gasses (H5).

These requirements and constraints can be refined and traced to individual system components through an iterative design and analysis process. As the main Administrative Authority, The Norwegian Directorate of Public Roads have the responsibility to ensure all aspects of tunnel safety. Consequently, by developing constraints they have the opportunity to communicate and operationalize Vision Zero in the Handbook N500.

6. Conclusion

Even if the Vision Zero has been a political desired concept in Norway for almost twenty years, the Vision Zero is still inadequately communicated through the hierarchical levels. The lack of constraints is preventing the Vision Zero from being conceptualised and implemented, which may cause differences in the understanding of Vision Zero between the hierarchical levels in the tunnel system safety management. The Vision Zero focuses on the consequences of accidents. Thus, knowledge about hazards and the constraints necessary to prevent fatalities and permanent injuries is important.

If self-rescue shall remain the leading principle of evacuation in the event of a tunnel fire, the Vision Zero must be operationalized through developing constraints. As a key regulating document in tunnel safety, the Handbook N500 (The Norwegian Directorate of Public Roads, 2016) needs a more proactive and functional based approach to safety based on Vision Zero principles.

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