Vision Zero on Fire Safety

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Abstract

Since 2010, Sweden has a Vision Zero policy on fire safety: no one should die or be seriously injured as a result of fire. Compared to the traffic safety model, however, the preconditions for successful implementation appear more immature and less convincing in the fire area. The purpose of this chapter is to illustrate, using the Vision Zero policy on fire safety as an example, how a Vision Zero initiative in a new area, where the conditions for governance may differ significantly from the area of inspiration, can be dealt with as a dynamic process to gradually establish credibility and effectiveness.

Globally, fire is a significant cause of death and injury. The general trend is toward a slow decline, especially among middle-income and high-income countries. The decline may be due to successful fire safety efforts, but also to other conditions affecting it indirectly. Both risk-increasing and risk-reducing factors determine fire safety. Risk increasing factors include an ageing population, an

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increasing diversity of possible ignition sources, and a change in the composition and amount of combustible materials present in our homes. The risk-reducing factors include generally favorable socioeconomic and technological developments, including concrete societal actions directed against fire risks such as the promotion of smoke detectors and sprinkler systems.

Fire safety is one of the oldest documented examples of societal risk management. City planning and construction were early influenced by fire safety considerations, while in contrast, the legal responsibility for residential fire safety has largely remained a private and individual matter. The situation is similar to the one that for long prevailed in the traffic sector, that is, the primary responsibility rests with the system's users, not with its designers.

The launch of the Vision Zero on fire safety in 2010 represented a clear boost in ambition. Along with the vision, a strategy intended to guide the work toward the visionary goal was also presented. The strategy included four items: information, technical solutions, local collaboration, and evaluation/research. Several actions were taken in line with the strategy, including a significant research effort and the development of a set of indicators to monitor progress.

Ten years later, the research effort has brought new knowledge that puts previous perceptions into partly new light. The notion that survival depends on the individual's personal capacities is strengthened. Adverse outcomes such as death and serious injury appear mainly linked to specific vulnerabilities of certain groups for medical and social reasons. Most fires are handled by the residents themselves without injuries and without assistance from Rescue Services; on the other hand, even minor fires can be fatal for vulnerable residents. This turns the problem framing toward social aspects rather than technical, since broad groups of residents lack the capacities needed, conflicting with the prevailing view that the individual should bear the primary responsibility.

Other findings relate to the proven inefficiency of certain measures for groups at elevated risk and the need for re-thinking and innovations to meet the challenges ahead. This includes extended inter-sectoral collaboration on a broader spectrum of residential risks besides fire, threatening the same groups for similar social and medical reasons.

This updated state of knowledge is now being used as a basis for renewing current national fire safety strategies. With reference to general principles of systems control, this chapter will discuss obstacles and challenges to establish a more robust and systematic national control of the fire problem in line with the Vision Zero policy. The appropriateness of launching Vision Zero policies in fields that are not yet ripe for systematic governance is also discussed. It is concluded that a Vision Zero initiative can still be meaningful and successfully pursued, provided that limitations in the ability to influence crucial elements in the system are openly identified and systematically addressed in a process in which strategical and policy developments interact with research and innovation.

Keywords

Vision zero · Fire safety · Systems approach

Introduction

Since 2010, Sweden has a Vision Zero policy on fire safety: no one should die or be seriously injured as a result of fire. Compared to the Vision Zero on road traffic safety, the Vision Zero on fire safety can be said to be less well known and less systematized in its implementation. It was launched as one among several Vision Zero policies in different areas where politicians and decision-makers became inspired by the Vision Zero on traffic safety and advocated similar approaches to meet other societal problems. Unlike the Vision Zero on traffic safety, where scientific and strategic progress can be said to have paved the way for the breakthrough and acceptance of a new paradigm (Belin et al. 2012), the Vision Zero on fire safety is still based on fragmentary scientific and strategic evidence. Rather, the Vision Zero on fire safety appears as an expression of decision-makers' desire to manifest will and determination before there is a clear picture of how the vision can be realized. Other Vision Zero policies have been established on similar grounds, which raise questions regarding the challenges involved in launching Vision Zero policies in new areas before they can be said to be scientifically and strategically mature for such a radical approach. The purpose of this chapter is to highlight these challenges, using the fire area as an example. More specifically, we wish to demonstrate how a long-term Vision Zero initiative in a new area where essential preconditions for adequate governance are still lacking can be dealt with as a dynamic and iterative process where such insufficient preconditions are systematically tackled along with more detailed solutions.

The chapter is structured as follows: first, we give a brief background on fire as a societal problem from Swedish and international perspectives, and how it has historically been managed. This is followed by a presentation of how the Swedish Vision Zero policy on fire evolved to the formal initiative that was presented in 2010. An essential part of the strategy associated with the policy was to initiate research in areas that were assessed to be of particular importance for the further implementation of the policy. The richer state of knowledge resulting from this research effort is summarized briefly, as well as its implications for the continued Vision Zero work. Emphasis is placed on achievements that can be judged of importance for a broader understanding of the nature of the fire safety problem, and how these achievements can be assumed to influence future strategic work. The chapter concludes with a discussion on the challenges a Vision Zero initiative can encounter when transferred to a new field where the preconditions for societal control may differ considerably, as compared to the traffic safety model.

Background

Globally, fire is a significant cause of death and injury. A total of about 120,000 people are estimated to die each year in fire (Ritchie and Roser 2018). Most of these deaths occur in low- and middle-income countries.

Reliable comparisons of the number of fire-related deaths between countries are largely lacking. In the EU, fires are estimated to be responsible for 2% of all fatal injuries (EuroSafe 2014). A report based on data from the International Association of Fire and Rescue Services shows steadily declining trends in countries such as Estonia, Germany, the United Kingdom, Latvia, Russia, and the United States since 2002 (Winberg 2016). Similar trends are shown in a Swedish study based on WHO data (Moniruzzaman and Andersson 2018). The latter research suggests socioeconomic development is the determinant that most clearly explains the differences between countries.

Sweden has documented a steady decline in fire mortality of about 60% from 1950s levels (Jonsson et al. 2016). Similar developments are observed in many comparable countries. Why this has happened remains largely unclear, but for Sweden, it is noted that the decrease has been most significant in children and younger ages. This has contributed to assumptions that expanded childcare and improved medical burn care may be important factors besides fire safety measures. Further, an ongoing shift in the medical cause of fire deaths, from burns toward intoxication, is observed, possibly due to changes in interior materials in Swedish homes. A vast majority of all fire deaths occur in residential settings.

Fire is a risk that accompanies people of all times, and fire safety is one of the oldest documented forms of societal risk management. For several centuries, many cities were ravaged by devastating urban fires (Garrioch 2019). As urbanization took off in the nineteenth century, Swedish cities grew rapidly, and a large number of them were hit by widespread fires (Bankoff et al. 2012; Schmaltz 1992). In 1874, the first Swedish national building and fire charter was adopted (Kongl Maj:t 1874). Rules on building height, firewalls, chimney-sweeping, and physical separation between buildings were introduced. Blocks with spacing between them replaced the previously clustered style of city planning. These measures proved effective; extensive urban fires ceased in the twentieth century and became limited to more finite block fires. This positive development continued, and the major fire problem then became fires in individual buildings. During the 1950s and 1960s, the concept of "fire cell" was introduced. A fire cell is a defined part of a building within which a fire can be confined for a given minimum period without spreading to other parts of the structure. This is achieved practically by requiring fire-resistant properties of the fire cell limiting surfaces – walls, ceilings, floors, doors, etc. This measure has been proven successful as well and has contributed to a deep reduction in fully developed fires in buildings. Most fires in apartment buildings are now limited to the fire cell where the fire started. The same applies to fatal fires; in a majority of residential fires with a deadly outcome, the fire is confined to the fire cell of origin (e.g., an apartment) or even to the single room of origin.

Besides regulations on construction and city planning, which impose certain obligations on industries, property owners, and municipalities, there is a strong tradition of responsibility of the individual in fire safety. According to the current Swedish legislation applicable to fire safety – The Civil Protection Act (Swedish Parliament 2003) – “the individual,” whether human or legal, has a primary responsibility to protect life, property, and the environment and not to cause fires or other accidents. In the first place, it is the individual who should take measures to prevent accidents and limit the consequences of accidents that may yet occur. The individual – for example, a resident of a single-family house or an apartment – is therefore assumed to have both the knowledge and ability to prevent a fire. The individual is also expected to have the skills and equipment (e.g., smoke detectors) needed to be able to act properly if a fire nevertheless should occur.

The fire safety framework described above has largely grown through evolution. The legislation is developed reactively, usually adjusted only in the aftermath of major and devastating fire events (Ewen 2018). Fire research gained momentum in the second half of the twentieth century but remain mostly technology oriented. An exception is research on evacuation, where behavioral knowledge and related methodology play a significant role.

Another aspect that might, in part, explain the lack of proactivity and adaptation to the social aspects of fire prevention is to look within the rescue service’s deeply ingrained culture. Most people choosing this career are focused on operational firefighting. Prevention tends to be regarded as an alternative or second-hand task. The strong internal professional culture, organized after military-type hierarchical models, with male dominance and a technical focus, probably makes it even harder to take on board knowledge and practices from non-fire science related areas such as public health or social care.

The Swedish Vision Zero Initiative

The first initiative toward a long-term strategical approach to reducing deaths and injuries in fires was taken by the then national authority having jurisdiction, the Swedish Rescue Services Agency, concurrently with the launch of the Vision Zero of road traffic in the late 1990s. At this time, it was primarily the ethical component of Vision Zero – it is hardly possible for a safety authority to argue for an ultimate visionary state other than zero – that was the motive. In 1997, the Swedish Rescue Services Agency submitted a fire prevention program to the government, proposing that “*The risks of fires should be continuously reduced. The numbers of deaths and injuries, as well as cases of serious damage to irreplaceable environment and property assets, should decline towards zero*” (SRV 1997). Partly as a result of this initiative, a systematic collection of facts about fatal fires and fire fatalities began at the Swedish Rescue Services Agency.

The current Swedish Vision Zero policy on fire safety was formally proclaimed by the succeeding nationally responsible sector authority, the Swedish Civil

Contingencies Agency (MSB[1]), in 2010. It was developed in response to a government initiative in which the Swedish government called for a national strategy on how fire protection can be strengthened by providing support to individuals (MSB 2010).

The initiative was motivated by an impression of slow progress and the recent occurrence of some high-profile fires with multiple fatal outcomes among immigrants. A supplementing strategy, intended to guide the work toward zero deaths and serious injuries, was formulated in four points:

Knowledge and communication
Technical solutions
Local collaboration
Evaluation and research

"Knowledge and communication" aimed at easily accessible and coordinated information for different target groups, such as those with special needs. Basic fire safety knowledge was judged essential to be included in schools and vocational training, as well as in training courses for newly arrived immigrants.

"Technical solutions" addressed technical innovations and the development of so-called forgiving systems that allow individuals to make mistakes without being seriously harmed or killed. Smoke detectors and extinguishing equipment in homes were particularly highlighted, as was the need to spread knowledge of other solutions. This point also underlined the need for strengthened fire safety in nursing homes.

"Local collaboration" addressed the importance of collaboration across sectoral boundaries to identify groups and individuals in need of special efforts and to reach out to property owners and insurance companies.

"Evaluation and research" was added as a final point to support future strategic development by bringing new knowledge. Among other things, a focused research effort on residential fires was proposed.

In support of Vision Zero for fire safety, a collaboration group and a campaign were launched (MSB 2020a). Further activities included the editing of a guide on "individualized fire safety," aimed at providing knowledge to, and guiding professional fire safety efforts toward, particularly vulnerable groups (MSB 2013a). In addition, an initiative on planned home visits was undertaken in 2016 (MSB 2020b). The latter activity was primarily inspired by the extensive home visiting activity in the UK, which is cited as an explanation of the substantial decline in death rates in fires there (Arch and Thurston 2013).

[1]MSB replaced the Swedish Rescue Services Agency in 2009, as a result of the Southeast Asian tsunami disaster in 2004, when more than 500 Swedes lost their lives. The intention was to create a broader national agency on crisis management and preparedness. MSB is the Swedish government's expert authority on fire safety and is responsible under the government for advice and support to the country's municipal rescue services and issues regulations and general advice to individuals and other actors.

Inspired by monitoring and follow-up routines employed in the traffic area in Sweden (Trafikverket 2020), nine indicators for fire safety were also developed (MSB 2013b). Four indicators related to outcomes (number of fatalities and serious injuries in fire per year, number of fully developed residential or fireplace-related fires per year, and societal costs of residential fires per year). The remaining indicators intended to reflect the implementation of fire prevention measures taken by society and individuals (presence of functioning smoke detectors, presence of extinguishing equipment, the proportion of municipalities with developed cooperation in the prevention of residential fires, knowledge of how to act in the event of a fire, awareness of fire risks in the housing environment). All indicators were intended to be regularly monitored, primarily through Rescue Services response records and complementary surveys.

Among these points, the proposed research effort has come to play a particularly important role in further strategic development for Vision Zero, as was envisaged when the proposal was presented in 2010. In 2013, three major research projects on residential fires were supported by MSB, all of them finalized and reported in 2017/18. The projects focused on different aspects related to fire safety, such as death and injury, social patterns, and technical solutions.

The Updated Status of Knowledge; What Is New, and What Are the Implications?

The aforementioned research has shed new light on residential fires in general, on contributing circumstances to deaths and serious injuries, and on the effectiveness of measures considered important for prevention. The research has also increased the awareness of remaining critical knowledge gaps, which consequently need to be addressed in further research efforts.

Residential Fires and How They Are Managed

In 2010, the state of knowledge was mainly based on data from Rescue Services call-out records collected through MSB. There was an awareness that these data might be skewed by underreporting, but in the absence of better data, generalized conclusions were nevertheless drawn on causes and consequences. In 2020, there is now a more complete picture of the total incidence of fire in Swedish homes based on complementary sources, leading to new insights and increased awareness of remaining uncertainties, such as:

There is more clarity on the fact that fires are frequent occurrences in Swedish homes, and that most fires are handled by the residents themselves. The total incidence of residential fires is estimated to be about four times the number to which the Rescue Services are deployed. Residential fires rarely lead to death or serious injury. This reinforces the image that fire outcomes primarily depend on the residents' own capacities.

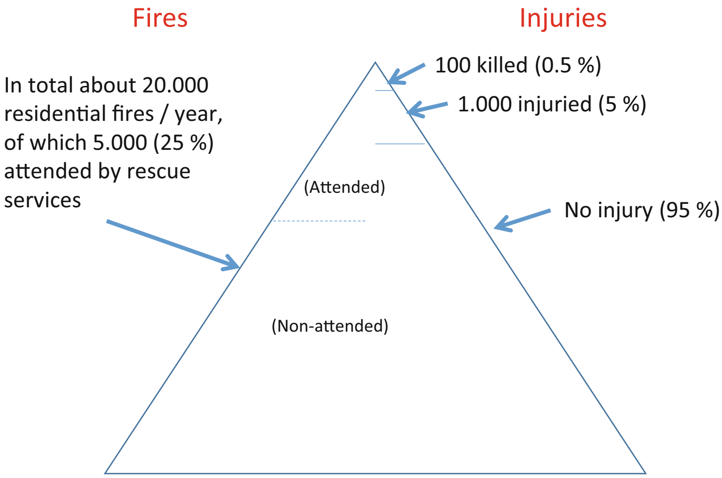

Fig. 1 Proportions between injury outcomes and rescue service attendance in case of residential fires in Sweden (derived from Jonsson 2018a, b)

The interest in creating an overall picture of the property damage caused by the large number of residential fires has increased.

The possibility of drawing conclusions about the causes of residential fires is surrounded by greater uncertainty, as most fires never come to the attention of the Rescue Services and thus are not subject to expert analysis. This also affects the state of knowledge regarding the relative danger of different fire causes, as current data collection does not capture information on the fires that residents handle themselves.

The updated knowledge status is summarized in Fig. 1.

Killed and Injured

One of the more important research efforts on fire fatalities, their circumstances, and the possibilities to assess the true number of fire-related deaths was carried out by Jonsson et al. (2015), by matching data derived from three separate sources. These were the National Board of Health and Welfare's cause of death register, the National Board of Forensic Medicine's register of autopsies, and MSB's fatal fire register. Through this matching, a validated and richer aggregate data set was created. From this work, it was possible to conclude that none of the registers alone gave complete coverage of fire fatalities and that the actual number of deaths was systematically underestimated by 20–25% in MSB's fatal fire register (Jonsson et al. 2015).

The understanding of fire-related deaths has thus developed considerably from 2010 to 2020. Data capturing from multiple sources is now secured, meaning that the previous under-reporting is under control. The statistics are now far more reliable. The importance of medical and social vulnerability among victims emerges more clearly. In the rare cases when a residential fire leads to death (<1%), the cause is usually the inability of the affected individuals to act appropriately in the acute situation, for example, for age reasons or because of illness, disability, or intoxication. There is no clear relation between the magnitude of the fire and the severity of the outcome in terms of death or injury. The majority of fatal fires are limited in size, with the victim most often found in the room of fire origin. Even very limited fires can be deadly for those who cannot help themselves, an insight that shifts the framing of the problem from a previously technically dominated perspective toward a more social one, including housing policy for people with special needs. Smoking, in combination with alcohol consumption, still appears to be a central problem among groups at risk. More in-depth analysis, however, reveals complementary scenarios, such as clothing fires, where influence of alcohol is rare. Medicines can also contribute to reduced alertness and ability in the aging population where prescribed drug consumption often is high (Sessing et al. 2017).

For the seriously injured, the knowledge is still very limited, but data from the national burn clinics, where the most seriously injured are treated, indicate a similar social profile as among deaths (Gustavsson and Nilsen 2018). The average age is slightly lower than among fatalities; on the other hand, a heavier social burden is indicated. In contrast, those with milder injuries and those who escape unharmed do not appear to differ significantly from the population average.

Although the Swedish Vision Zero on fire safety encompasses all types of fires, the policy has in practice been restricted to unintentional residential fires. While a clear majority (about 70%) of all fire deaths in Sweden result from such fires, a considerable proportion also relates to non-residential and intentional fires. For instance, around 10% result from post-crash fires in vehicles, and about 13% relate to intentional fires, mostly suicide (Jonsson et al. 2017). More study of this group is needed; currently no central measures to counteract these deaths or injuries appear to have been implemented, although some local Rescue Services in recent years have activated themselves in the field of suicide prevention (MSB 2009). It is important that future strategical developments also incorporate considerations on non-residential and intentional fires.

The toxicity of fire gases is the most critical factor from a survival point of view (Stec and Hull 2016). The majority of fatalities now die from poisoning (Purser 2010). In addition, toxicity contributes by incapacitating the victim before death occurs. The incapacitation process is comparatively less well studied in the published literature. Given that fire gases usually contain a mixture of very potent toxic gases such as cyanide and carbon monoxide, it is, however, reasonable to assume rapid impacts in those who cannot immediately escape the room of origin.

Fatalities and property losses from fires represent separate problems and should be understood from separate points of view. Deaths are caused by medical impacts on living organisms by the fire's by-products: gases and heat. Property damage, such as structural damage to buildings, is mainly caused directly by the oxidation process of the fire itself. Some property damage also results from smoke or extinguishing materials such as water. Costlier property damage is often caused by larger fires, while most fatal fires are limited in size. Deaths usually occur in the initial phase of the fire, while property damage culminates later as the fire grows in intensity. Thus, measures to prevent lives will also reduce the risk of property damage.

Effectiveness of Measures

In 2010, smoke detectors were highlighted as the single most important measure to improve safety. Ten years later, there is an increased awareness of the limitations of the effectiveness of smoke detectors in relation to vulnerable risk groups, with accompanying requirements for complementary individual and needs-adapted measures (Runefors 2020a). These include technical equipment such as detector-activated sprinkler systems, but also social initiatives such as the provision of adapted housing for those with special needs, meeting higher safety standards. The latter, in turn, raises a broader perspective on fire safety, including more factors and actors than originally considered.

Smoking is a leading source of ignition as regards fatal fires. Therefore, there were considerable expectations for the so-called self-extinguishing cigarettes as introduced in both the USA and the EU around 2010. The cigarettes were designed to stop glowing when left without active smoking. However, studies have shown that the cigarettes do not seem to fulfill this criterion in practice (Bonander et al. 2015), and that the testing method poorly reproduces real situations (Larsson and Bergstrand 2015).

A particular problem is the extensive introduction of various types of artificial materials in buildings, including dwellings, since the 1950s. Different plastic materials with the potential to emit highly toxic gases are present in many interior products and finishes (Seo and Son 2015). Energetic petroleum-based polyurethane foam has largely replaced natural materials in furniture upholstery. The above developments have led to the presence of significantly more flammable material in larger volumes inside an average dwelling. This has significantly shortened the time until very high temperatures (flash-over) are reached and also leads to a faster release of combustion gases with very high toxicity (Kerber 2012; Blomqvist 2005). The problem has been understood for a long time, and early attempts were made to counteract this by the addition of flame retardants. However, these agents, usually bromine compounds, have serious environmental and health effects and are in many countries banned or on the verge of being phased out (Chivas et al. 2009). Research to find environmentally acceptable alternative solutions are underway (Brandforsk 2019).

The Rescue Services annually rescue a number of people who would otherwise have died (Runefors 2020b). However, the ability to save more lives is strongly limited by their response time (Jaldell 2017). In practice, few can be reached as quickly as would be needed for rescue operations to be considered a reliable safeguard for those who cannot help themselves in case of a fire at home. Swedish standards for fire protection in dwellings still presuppose that residents can evacuate on their own (Boverket 2019). Yet those rescued by Rescue Services are, on average, younger, more often cohabiting, and more commonly found in spaces other than the room of origin as compared to those who die (Runefors 2020a, b). The gender balance is also more even. Those rescued generally seem more capable than those who die, perhaps by being able to move to a safer space while awaiting assistance. Trials with complementary semi-professional or volunteer response resources, which may arrive at the scene earlier than the Rescue Services, show some potential to increase the ability to rescue and thereby increase survival (Sund and Jaldell 2018).

Knowledge Gaps and Innovation Needs

Besides generating new knowledge that can be directly utilized in prevention work, research also helps to increase awareness on remaining knowledge gaps. As the research front moves forward, new issues are identified whose importance may earlier not have been fully understood.

For example, since most residential fires remain unattended by the Rescue Services, there is still insufficient knowledge about the total incidence of fire in Swedish homes, typical patterns and details of unattended fires, and how these fires are normally handled. It emerges now more clearly that death and serious injury from fire are among the exceptions, while the typical situation is that most fires are controlled by the residents themselves without serious consequences. This underlines the need for a wider comprehension of residential fires to better understand under which specific and exceptional circumstances a fire leads to serious consequences. In-depth studies and learning processes on fires with fatal or seriously outcomes need to focus more intensely on such specific conditions.

Further knowledge is also needed on the conditions that facilitate the successful rescuing of people who would otherwise die in life-threatening fire situations. The abovementioned circumstances, as indicated by Runefors (Runefors 2020a, b) and Sund and Jaldell (2018), need to be explored in more detail.

Those who incur serious injuries remain to be studied with the same depth and breadth as those who die. Some similarities are already indicated between the two groups. However, the fact that people in this group survived suggests that there may be significant differences as well, carrying potential information on protective factors critical for survival.

The knowledge is still sparse on the physiological effects of toxic fire gases. This knowledge is crucial for the understanding of the time available for rescuing helpless persons left in the room of origin, as well as the mechanisms and speed of incapacitation of the victim.

The contribution of pre-hospital and hospital care to reducing mortality and injury severity associated with fire needs to be further studied. Proper care of a seriously injured person at the fire scene and during transportation, such as adequate antidote treatment and breathing support, as well as the quality of the subsequent specialist care, is often crucial for survival and successful restoration. In contrast, incorrect pre-hospital diagnosis and treatment can further aggravate the harm.

The role and measures of the Rescue Services should be studied in a broader context. The social dimension of the residential fire problem calls for more extensive involvement from other societal actors to take the preventative work forward. At the same time, studies show that Rescue Services can make very cost-effective efforts outside their core area, for example, in cases of sudden cardiac arrest. The vulnerable target group identified here is surrounded by several other parallel risk and insecurity issues at home, all of them originating from similar vulnerability circumstances linked to age, ill-health, and disability. The time seems ripe to seriously explore broader models of cooperation around the wider risk spectrum shared across sectors.

Trends and Implications

In 2010, an aging population, combined with an increasing proportion of elderly remaining living at home, was assumed to pose the risk of a significant increase in the number of people dying in fire. Also, social and economic factors were judged to contribute to the risk of death, which called for actions targeting particularly vulnerable groups. Alcohol and drug prevention was also considered an essential part of fire safety work. These judgments remain in 2020 with increased weight. In addition, the knowledge of ethnicity as a possible contributing factor was in 2010 seen as necessary to strengthen. This assessment no longer seems as relevant, as additional studies do not support the assumption that an immigrant background is a significant risk factor for fire mortality. On the other hand, there has been rapid technology development that was not really predicted in 2010, but which in 2020 appears worrying from a fire safety point of view. Digitalization has led to a sharp increase in rechargeable electrical products in living environments. An increase in fire problems can also be foreseen due to the transition to a fossil-free society. This development is expected to lead to increased multi-dwelling construction in wooden materials, a sharp increase in rechargeable electric vehicles, local electricity production via solar cells and storage in lithium-ion batteries with a high energy content (Andersson et al. 2019).

Finally, the new state of knowledge brings new policy implications that need further study and development. These include housing policy, social services, home-based health care, and how society generally should provide safe, secure, and attractive housing for a growing elderly population, and other groups with limited abilities in the event of fire. What is the potential for initiatives such as changes in housing policy, a broadened content in social needs assessments, and home visits? What support in the form of amended legislation, directives, and resource allocation is needed to promote a more extensive and intensified development of societal fire safety? Preventative and Vision Zero approaches from adjacent areas suggest a need for a broader systemic approach to housing risks, in line with the principles adopted in traffic and occupational safety, where responsibility for safe conditions is seen to rest with several actors in cooperation.

Continued Strategic Development Work

The richer state of knowledge gained from research has created incentives for renewed strategical initiatives based on science rather than traditional experiential learning. First up was the Swedish Fire Protection Association (SFPA), a nonprofit organization working for “A fire safer Sweden.” SFPA is supported by a number of stakeholders in the field of fire safety, such as the insurance industry, and works with standard development, knowledge dissemination, and advocacy in the fire field. A parallel strategic update has been initiated by MSB. This work is ongoing at the time of writing, which means that we here limit ourselves to summarizing what we perceive as broader achievements and considerations that generally influence both processes.

One such insight concerns the need for a more comprehensive “systems” approach to the problem of residential fires, as indicated above. It is becoming increasingly clear that the risk of being killed or seriously injured in fire is due to several interlocking factors, which in turn link back to the responsibilities of many different actors. Another overall insight concerns the need for a systematized collaborative approach across sectors regarding all these factors and actors toward the Vision Zero targets.

An interesting model for describing and analyzing the possibilities of controlling a system, in this case reviewing the potential of a Vision Zero strategy, is the so-called GMOC model. GMOC is an acronym that stands for Goal, Model, Observability, and Controllability. According to general control theory (Kalman 1959), four criteria represent prerequisites for controlling any system. Although control theory is mainly focused on automated systems, GMOC has found applications in fields such as human decision-making and human-machine interaction (Tschirner 2015).

The four criteria include:

G: The need for an objective – the Goal criterion
M: The need for a model of the system – the Model criterion
O: Possibilities to determine the current states of the system – the Observability criterion
C: Opportunities to influence these states – the Controllability criterion

The goal criterion is about defining what is to be achieved; in this case, fewer deaths and serious injuries from fire. The goal should be directed toward the adverse end outcome (e.g., deaths and serious injuries) instead of focusing on single upstreams exposures or determinants (e.g., fire occurrence). There are many examples of the latter kind of policies that prove ineffective because they are based on simplistic and sometimes erroneous notions on cause-effect relations, such as zero tolerance on drug use to prevent drug-related mortality, to mention one.

The model criterion relates to the need for a commonly shared view of what the “system” looks like, who designs it, what it is aimed for, the relationship between inputs and outputs, and why, in certain circumstances, it also entails risks for its users. In this case, it is reasonable to consider housing as a system. The primary purpose of housing is to provide shelter and security for its users. Unfortunately, however, housing is also the arena where most injuries occur. It is necessary for the sake of prevention to identify significant circumstances contributing to these injuries and subject them to intervention with the involvement of those actors which directly or indirectly determine the related risks.

The observability criterion means that relevant system states and dynamics can be monitored over time by valid measures and indicators. If the goal is to reduce the number of deaths and serious injuries, monitoring procedures for these variables must be ensured to identify actual states and to follow and evaluate progress in the preventive work. The same applies to different determinants of need to influence, for example, smoking and alcohol habits, the presence of smoke detectors, the proportion of single residents, the proportion of residents with disabilities, etc.

The controllability criterion refers to the need for a preventative "toolbox," that is, access to evidence-based methods with credible ability to influence the outcomes targeted for change. If adequate tools are lacking, it does not matter how well a system is defined, and its mechanisms and determinants are modeled and understood. There is still no ability to influence the outcome of interest.

To the controllability criterion, we wish to add an aspect highlighted in the literature on "governance" on how to develop systematic societal control of broad and complex problems affecting several societal sectors (Hedlund and Montin 2008). It is not enough that control is technically possible; there must also be a governing system in place that ensures policy implementation. To a large extent, this is about providing policymakers and stakeholders at different levels of the system with the necessary information and ensuring their mandates and resources. Communication and feedback vital for a proactive safety control include objectives, priorities, actual status in relation to objectives, and awareness among involved actors of the potential safety effects of their decisions. A proactive governance strategy should aim at defining the boundaries of safe performance, making these boundaries visible to decision-makers, and counteracting pressures that drive decisions toward the boundaries (Rasmussen and Svedung 2007).

Table 1 represents an attempt to review the current fire safety work by employing the GMOC model's criteria. As can be seen, a great deal of work remains to be done before even elementary system control possibilities can be said to be in place concerning the prevention of deaths and serious injuries from fire.

The preconditions for a well-founded prevention strategy are undoubtedly better regarding fatalities, with adequate status monitoring and a growing understanding of relevant mechanisms and determinants (the model criterion). However, there is still reason for skepticism on effectiveness and success when it comes to the possibility of influencing the problem. The main obstacle is the lack of a politically supported governance system across sector boundaries, as many of the determinants, such as medical and social, lie outside the mandate of the expert authority itself (MSB).

In the case of non-fatally injured persons, primarily those seriously injured as are explicitly addressed in the vision zero policy on fire safety, the basic conditions for systems control are still largely lacking. There is no regular monitoring routine in

Table 1 Illustration of prerequisites for systems control and actual status regarding fatal and serious injuries from residential fires

Criteria	Fatalities	Serious injuries
Vision/goal	Established by MSB at agency level	Ditto
Observability/ status monitoring	Ongoing data collection and analysis with good quality	Inclusion criteria and monitoring routines are still lacking
Model	Good problem comprehension on groups at risk, injury mechanisms, and significant risk- and protective factors from recent research The broader system including related actors remains to be modeled	Weak problem comprehension due to lack of research. Injury etiology largely unknown
Controllability/ governance	Major limitations: Lack of effective measures Lack of governing system Obsolete legislation Lack of political support	Ditto

place, leaving the knowledge-base for this group relatively unclear, including related determinants and potentially effective countermeasures. The lack of a national cross-sectoral governance system characterizes this category as well.

The same applies even more to property damage. However, as this aspect of the problem falls outside the objective of the Vision Zero policy on fire, it is not further commented on here.

This presents several fundamental challenges for the continued Vision Zero work on fire safety.

The provision of basic statistics and the use thereof need to be significantly developed, especially concerning serious injuries. Major determinants of deaths and serious injuries from fire should be monitored and followed up on a regular basis as well.

The modeling work needs to be intensified. Actors having an impact on housing safety need to be identified on a broader scale and assigned roles and responsibilities in the collective fire safety work. It is also crucial that the injuring process itself (corresponding to the impact from crash violence in traffic) is modeled to increase the understanding of the time interval for action that is available to a person left in the room of origin in the event of a fire. This knowledge is crucial for proper system measures aimed at improving the individual's chance to self-evacuate and the potential success of external rescue operations.

The "toolbox" needs further improvements with new and innovative methods of fire prevention, such as detection, alarming, extinguishing, evacuation, and rescuing. Not least, new forms of housing need to be considered for those who, despite supportive efforts in regular homes, are at risk of acute danger in the event of a trivial fire incident.

Societal governance in the fire safety area needs to be fundamentally upgraded. Like the traffic safety model, the Vision Zero policy for fire safety needs clear support from the top political level, mandating a national body to coordinate the work across sectors, and an obligation for other sectors concerned to participate in the work. The legislation needs to be reformed, supporting such a broadening of the fire safety work, including its approach to liability.

All these steps need to be underpinned by continued knowledge development and innovation. Research and prevention need increasingly to take the medical and social dimensions of the problem into account.

Conclusions and Future Work

Each risk area is unique in terms of context, typical sequences of events, and possible consequences. Therefore, it is not possible to merely copy models and measures from one area to another. On the other hand, there are often parallels allowing some generic lessons to be transferred, not least in terms of general procedures and approaches in safety work. Here, with the fire area as an example, we wish to discuss some more universal lessons learned on Vision Zero work in areas where essential conditions for systematic societal governance may remain weak. In such situations, we claim, the focus must be on establishing these conditions.

Fire and traffic share the feature that both areas entail injuries and deaths. In traffic, it is mainly the crash violence that harms and kills, while in the case of fire, the corresponding mechanisms are the exposure to heat and combustion gases. It has taken decades of research and development in the field of traffic to reach consensus on the crucial importance of controlling crash violence as a core strategy to improve road safety. In parallel, there is a persistent narrative on the role of human error. Crash violence is determined by the design of the traffic environment, vehicles, regulations, etc., that is, conditions determined by actors other than road users. The parallel focus on the responsibility of the road user thus tends to become an excuse for dangerously designed traffic environments and vehicles. The Vision Zero in road traffic can be said to represent the visible result of a paradigm shift in which policy-makers have decided to partly reverse the division of responsibilities: "responsibility for road safety is shared between those who design and those who use the transport system. The ultimate responsibility for safety rests with the designers" (Swedish Government 1997). Underlying this statement on the overall responsibility of system designers is a judgment that to err is human and that the transport system, therefore, needs to be designed in a way that compensates as far as possible for simple mistakes that anyone can make. The traditional idea of the individual's primary responsibility can thus be said to be abandoned in the current theory and practice of road safety work, even though this view is still apparent in legislation and law enforcement practices.

For the Swedish fire safety work, the Vision Zero policy on traffic and its indicator-based follow-up system has undoubtedly served as a source of inspiration since the late 1990s. There has been a genuine interest in establishing something similar. However, the analysis of the core contents of the Vision Zero philosophy in the fire area has remained relatively superficial, and the fire sector has not yet been able to take the full step toward a corresponding paradigm shift. The thinking has to a large extent remained inside the existing legal framework and the extensive work done in the field of road safety to identify and involve system designers does not seem to have been fully understood and replicated in fire safety.

There is a persistent narrative on the responsibility of the individual in fire safety as well. This view is reinforced by the fact that fires, in addition to having different injury causes (heat and toxicity), also differ from road accidents in terms of the time available for action while the accident happens. Traffic accidents usually cause instant harm, while hardly anyone is injured at the onset of a fire. A fire takes time to escalate, which means that the individual responsibility is seen as twofold; to ensure that fire does not occur, but also to extinguish or evacuate before the fire becomes critical. Rescue Services' response times are usually not short enough to guarantee safety for residents, which means that fire safety in ordinary homes is considered to rest on the premise that residents themselves are able to act appropriately in the event of a fire (Boverket 2019).

Thus, compared to the traffic area, the broader systems approach is still lacking in the fire area. Consequently, the Swedish vision zero initiative on fire safety cannot be described as a mark of a scientific and practical paradigm shift similar to that in traffic. The situation is therefore reversed in fire safety, leaving a flavor of wishful thinking. Instead of an emerging knowledge base forcing a new groundbreaking policy, the new policy comes first while the scientific foundation has to be constructed afterwards. The reversed approach may seem irrational, but can also be seen as a challenge and an incentive for further research, innovation, and policy development. It is this opportunity we wish to highlight here.

Another difference lies in the prevailing traditional intra-professional culture in the fire area, in contrast to the broader and more cross-sectoral approach of the transport area. Traditional exertion of authority, which characterizes fire safety, mainly consists of regulation and enforcement. The regulations issued, based on existing legislation, usually imply incremental improvements, reflecting traditional mental models of liability, of fire causation, and of measures to be taken. The rules tend to define minimum levels only, following the natural logic of formal rule-based processes. Unless such a process is complemented by initiatives relying on other drivers than compliance and also exploit, for example, the innovative powers of industry, there are reasons to be pessimistic about the potential for more significant changes in trends.

Again, the fire area here should be able to find inspiration from the traffic area's Vision Zero work. Several innovative solutions have been implemented in the road infrastructure, but the major leap in improvement is undoubtedly to be found in technological developments in the automotive sector. These achievements are not a priori driven by legislation, but by consumer demands and competition. Airbags and other safety systems are now standard equipment in every new car. But, for those buying a new villa, often at a cost that exceeds a car's manifold, few or no safety systems against fire or other accidents are included in the standard delivery.

The GMOC model presented above with its four criteria can serve as a theoretical framework for understanding what needs to be in place for a Vision Zero initiative to appear meaningful and practicable. The basics for controlling dynamic systems have been known since the steam engine's introduction in transportation and industry (Maxwell 1868). This theoretical framework has been further developed over time and led to applications in high-tech areas such as aviation, nuclear power production, and space expeditions. Those are areas where high values are at stake, and where all related risks, therefore must be meticulously controlled. These applications are all characterized by interactions between human, technological, and organizational components, so-called sociotechnical systems (Rasmussen and Svedung 2007). The principles have been subsequently disseminated to broader areas of risk management already in the 1970s and 1980s, first to the field of occupational health and safety, with its industrially dominated culture and understanding on issues like organization, reliability, process control, and quality assurance, and then further to areas such as product safety and patient safety. In these areas, risks are commonly understood as the result of an interaction between people, technology, physical environment, and organization where all components contribute and where weaknesses in one element, for example, the human part, can be compensated by other parts of the system. The notion that risks can be systematically controlled is fundamental. The Vision Zero policy in traffic safety was the result of a breakthrough for a systems control approach to traffic safety as well. It became increasingly clear that accidents are not just to blame on road users. Infrastructure, vehicle standards, regulations, etc. play fundamental roles in addition to human behavior. Therefore, road safety also more clearly emerged as controllable by society. The scientific achievements came first, and the policy innovation Vision Zero was prompted as the logical result. The goal criterion could be formulated based on confidence in the possibilities of long-term systems control. The model criterion was already met through a thorough conceptualization of the interaction between road users, traffic environment, vehicle technology, regulations, and monitoring, combined with an in-depth understanding of the crucial importance of crash violence in the severity of outcomes in the event of an accident. Observability was enhanced by improved data collection on outcomes and major determinants (indicators). With broad top-level political support and supervision, better conditions for controllability were created and further strengthened through systematic feedback to the various system sub-designers and other actors involved.

The fire area differs considerably from the aforementioned situation. A Vision Zero policy was launched without a corresponding scientific underpinning that preceded the Vision Zero on traffic. Through the GMOC model, it is possible to identify that more development is needed to establish a controllable system on fire safety, and it is these needs that ongoing strategy work now aims to meet. The goal criterion (no one should die or be seriously injured) remains fanciful as long as data capture on deaths and seriously injured, and evidence of prevalent types of societal interventions, is not secured. Hence, there is still a lack of credibility in both the long-term vision and the milestones set. The model criterion is the weakest point. Housing is a system that is still waiting for its modeling. It should be seen as a socio-technical system in the same way as working life and transportation, with a spectrum of associated risks, including fire. Risk levels in housing are, to a large extent, determined by system designers such as property owners, the construction industry, social services, regulatory designers, licensees, and manufacturers and suppliers of installations and movables. As far as fire is concerned, it is evident that significant responsibilities fall on these different system designers, especially as it is becoming increasingly clear that a growing proportion of residents lack the skills to ensure their fire safety themselves (Nilson et al. 2019). Also, there is a need for more elaborated modeling of the dynamic process of deaths and injuries in case of fire (corresponding to traffic crash violence), and how this process can be affected by different types of interventions. In particular, the time aspect is critical for the dimensioning of rescue functions for residents lacking the ability to evacuate on their own. The observability criterion is linked to the measurement of the variables one wants to modify (numbers of deaths and serious injuries), occurrences and characteristics of residential fires, as well as significant determinants of the problem, such as proportions of elderly people and single residents and disabled people. Finally, the controllability criterion is linked to the possibilities of influencing the problem. The Vision Zero in fire safety is still only adopted formally by the national fire safety agency itself, MSB, not by the parliament or government. MSB has no mandate over other sectors concerned, meaning that the conditions for proper governance of fire safety across sectors are still very limited.

The establishment and acceptance of a vision zero initiative addressing a cross-sectoral problem area must most probably be made at a top policy level to ensure adequate conditions for governance and controllability.

All in all, the Vision Zero initiative on fire safety appears still immature and based on fragmented evidence. Therefore, the ongoing strategy work should be largely focused on creating better conditions for effective governance. The strategy linked to the launch of Vision Zero on fire safety in 2010 reflected the status of knowledge and experience at that time. One crucial insight is the significant knowledge gaps on residential fires, in particular that related to deaths and injuries. An essential component of the strategy was, therefore, to initiate further research. Ten years later, there is now a richer knowledge base in several respects, both in terms of causes and countermeasures, but also on the need for a more comprehensive system approach and a strengthened societal governance approach. These new insights now constitute inputs to the ongoing strategy work described above, forming the next generation of strategy. An essential component of the new strategy, as in the previous version, will be to continue to identify remaining knowledge gaps that need to be addressed in upcoming research and innovation for future generations of strategies. In this way, a Vision Zero initiative can be described as an iterative process where knowledge acquisition and strategy development interact and strategies are continuously refined based on "best practice and knowledge" available at each time. From this view, the "reverse approach" rather appears as a reasonable and rational way of dealing with inspiring role models in parallel fields by formulating challenges for one's own area that accelerates a development that would otherwise have taken much longer.

In light of the above, the main lessons can be concluded as follows:

– Establishing Vision Zero initiatives in new areas where fundamental prerequisites for systematic control and governance are lacking may still appear valuable provided that the Vision Zero approach is used as a challenge to systematically establish the missing preconditions. The GMOC model is a valuable tool in this work.
– Knowledge gaps should never be accepted as an excuse for the lack of strategies. Strategies always need to be developed and updated based on the best knowledge and experience available. On the other hand, these gaps must be subjected to new research and innovation so that what today may seem utopian will tomorrow appear possible, realistic, and affordable. In this way, vision zero work can be seen as a planned and controlled dynamic process in which strategy and action programming interact with research, development, and innovation.
– Governance takes place in a political context where the scientific rationale often has to be balanced against many other considerations. Vision Zero initiatives must, therefore, enjoy broad political support from a level that is respected among all sectors affected by the vision. The body appointed to lead the work needs strong top-level political support to ensure sustained participation from other actors.
– Governance and cooperation between different actors need to be orchestrated based on a shared understanding of the nature of the problem, its determinants, and the roles and responsibilities of all actors involved. A systems approach is the key to this.

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