

Driver distraction and advertisements on objects and buildings along roadways and highways

The road to a comprehensive framework



Master Thesis

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Preface

Dear reader,
Dear committee,
Dear friends and family,

Thank you for reading this preface and thesis. It is the final chapter that I write as a TU Delft student. A chapter about how the journey of this thesis was like. The thesis itself is also a final chapter, as it marks the end of all the previous work I have done during my time as a student in Delft.

In November 2024, it was time for me to search for an interesting subject for my master thesis. After thinking out loud for quite some weeks, it was my father who send me a graduation vacancy from Movares. A graduation assignment about roadside advertising along Dutch highways, by which I was immediately enthusiastic. Early December 2024 I visited Movares for the first time to speak Martin Wink about this subject, and this formed the start of my thesis journey in March 2025. Two years earlier, I wrote an essay under the supervision of Oscar Oviedo-Trespalacios, which is still one of the essays I'm most proud of during my time at the TU Delft. I knew that Oscar is a known researcher in the field of driver distraction, and thus I reached out. Oscar and Martin were both enthusiastic and supportive from this very beginning and after the addition of Maarten Kroesen as chair, my committee was complete.

I want to thank my committee for everything they've done for me, for the subject-specific expertise (thanks Oscar and Martin!), for quickly answering all my tiny questions regarding the graduation process (thanks Maarten!), for keeping me on my toes (thanks Martin!) and of course for all the critical feedback (thanks all!). Furthermore, I want to thank all the people at Movares for showing interest in me and my topic, thinking along and having great chats in general the past ten months. I also want to thank Ronald Vink and Stan Thijssen from Ocean Outdoor and Pablo Nuñez Velasco from Rijkswaterstaat. The conversations and insights I have got from them in an early stage, helped me understand the world of roadside advertising and policy making better.

Special thanks go to my friends and family. My parents, for being supportive during primary school, during my master thesis, and every single moment in between. And to Imke, my sister, for studying in the room next to me for most of my time as a student, as I lived at home in Rotterdam with my parents and sister for my whole study career. However, for the last three months of my thesis, I had the opportunity to temporary live in Utrecht, close to the Movares office. I want to thank my friends Melanie and Hugo for this opportunity and for adopting me as roommate for this period. Furthermore, I am grateful for all the friends I have and have made during my time in Delft. Jens and Niels, who I have known since the first year of high school, and with whom I followed the same bachelor *and* master study for more than six years now. Especially during the bachelor, during covid, I was grateful to be able to study together with you. Over the past four years, I became an active member of WTOS, the student cycling association of Delft. I want to thank all my friends there for making my student career truly *the best time of my life*. In particular, I want to thank Jewel for studying together so many times and for finishing her master thesis one year before me, so I could always ask you anything. Last but not least, during my board year at WTOS, year 41 (academic year 2023-2024), I learned and experienced so much more than I could ever imagine beforehand. I can never be thankful enough for that.

*Jelle Vos
Rotterdam, January 2026*

Summary

Distracted driving is an important safety issue, accounting for a substantial amount of crashes leading to casualties and injuries. Drivers can get distracted on the road by various things, roadside advertising being one of them. Driver distraction with relation to roadside advertising has been studied for years, with research showing that roadside advertising successfully competes for the attention of road users. Safety performance indicators as headway distance, lane keeping and speed regulation can be impaired by the presence of roadside advertisements. This causes a potential safety risk for road users. Existing literature, however, is inconclusive on the extent of this effect. Road authorities are responsible for their road users and for mitigation of potential safety effects. For this mitigation, there are guidelines in place regarding the placement and design criteria of roadside advertising objects. Roadside advertisements are proven to be effective for the marketing of companies and with rapidly changing technologies, the roadside advertisements guidelines should be up-to-date as well. This thesis aims to provide an overview for policymakers to gain insight in what evidence is currently available to effectively shape policy guidelines. This is done by answering the following main research question:

What are the differences between current evidence-based insights and the Dutch policy framework about placement of roadside advertising objects along (high)ways?

The Dutch policy guidelines are built upon an evidence base which was last revised in 2019. This research aims to strengthen this evidence base of (scientific) studies. Another research objective is to strengthen the evidence base by providing an overview of policy guidelines of other countries, so that there is a small, but concise database on best practices, where policy makers can learn from. Third, the aim is to gain insight into which extent roadside advertising has an influence on road safety.

For updating the scientific fundament of policy guidelines, a literature review is conducted. Twenty-four articles ranging from 2019 to 2025 were reviewed. During this literature review, new and confirming insights are identified. These insights can be incorporated into the Dutch framework, which helps strengthen the evidence base.

The Netherlands is a well-performing country on road safety. As such, only the guidance documents of well-performing countries are critically reviewed to gain valuable insights and learn from international contexts. To come to a selection of similar countries, a pragmatic but structural approach on road safety performance and cultural similarities is used. The reviewed documents showed that international guidelines are, just as the Dutch framework, built upon a scientific fundament. Policymakers are responsible for implementing the knowledge derived from scientific research. However, pragmatic approaches cause that the implementation of guidelines and their level of detail differ across countries.

As crash data is often a key performance indicator for road safety, quantitative evidence on risk figures of roadside advertising is longed for by policymakers. Existing literature showed that this is difficult to obtain, due to methodological limitations of available crash data and the crash data analysis.

This thesis aimed to gain insight to the extent of safety impact by digital billboards. A pragmatic before-and-after analysis is conducted by the use of crash data from 2014 to 2024 and digital billboards provided by Ocean Outdoor, a large advertising company in the Netherlands. Twenty billboards were analyzed on the numbers of crashes in their vicinity during the period before and after the placement or digitization of the billboard. As comparison group, the general trend of crashes on Dutch highways is used. The results were mixed and inconclusive on the individual level but showed statistical significance for a positive safety effect on a higher, aggregated level. This is contrary to what one would expect based on existing literature, but it should be carefully interpreted as there are several limitations in place. No site-specific control groups were used, where this is often done to have a best possible comparison. Another limitation is the presence of small numbers of crash occurrence. This leads to more influence of

confounding factors, as small numbers can fluctuate more during the years than the general trend of crashes does. Another important aspect of this analysis is the Dutch road safety system in general. As the Dutch roads are well-performing and strongly regulated by the government, this makes the road system rigid to individual interventions as the placement of a digital billboard. This could be an explanation that no negative safety effect is obtained in this crash data analysis.

This thesis concludes that although conclusive evidence on risk figures is difficult to obtain, other safety performance indicators are well studied in previous research and are therefore useful when revising 'best practice' guidelines. The scientific overview provided by the literature review as well as the overview of international best practices can both be used in shaping the Dutch guidelines. Practical, detailed recommendations are provided for policymakers. There are concrete examples provided of studies that can be added in the Dutch guidelines as evidence-based foundation. Another recommendation, following from the comparison analysis of other countries, is to use more examples in the Dutch guidelines. For example, illustrations of desired and undesired images and a list of undesirable call-to-action texts and could be included in the Dutch guidelines, as done in several other countries. For further research, it is recommended to conduct the crash data analysis with only newly placed digital billboards, as the current analysis also included digitized billboards. Together with site-specific control groups, this could lead to more stable results. However, small crash numbers remain a limitation of a before-and-after analysis.

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1. Introduction

1.1. Background

1.1.1. Driver distraction

Distracted driving is an important safety issue regarding road safety, since it can lead to crashes, injuries and fatalities on the road. In the United States, distracted driving is identified to be primarily involved in 8% of fatal crashes and 12% of injury crashes in 2022 (NCSA, 2024). In a crash analysis study in Australia in 2013, it is found that in 16% of serious casualty crashes, driver distraction is the leading cause (Beanland et al., 2013). Numbers regarding to crash rates in The Netherlands, with regard to driver distraction are very, very limited. A Dutch study in 2015 tries to estimate but came no further than 10 to maximum 100 fatalities (Stelling & Hagenzieker, 2015) on a total of a little over 600 traffic fatalities in 2015 (CBS, 2024). In addition, these estimates we're mainly based on research done in other countries (Stelling & Hagenzieker, 2015).

“Driver distraction is diversion of attention away from activities critical for safe driving toward a competing activity, which may result in insufficient or no attention to activities critical for safe driving” (Regan et al., 2011, p. 1776). When thinking about distractions while driving, the usage of mobile phones directly comes to mind. And while this is certainly one of the more important type / causes of distraction (Pless & Pless, 2014), there are plenty of other sources that lead to distraction while driving. Regan and Hallet (2011) mention that a competing activity can either be driving-related or non-driving related, be either derived from inside or outside the vehicle, and can occur involuntary (system-initiated) as well as driver-initiated (Regan et al., 2008). Examples of distractions are the use of mobile phones, looking at billboards, looking at other traffic participants, listening to loud music and so on (Regan & Oviedo-Trespalacios, 2022; Rejali et al., 2024). In this thesis, the focus is on the latter category: distractions by roadside advertising.

The World Health Organization (2011) categorizes different driver distractions into four types:

- Visual distraction – eyes are away from the road
- Cognitive distraction – mind is away from the road
- Physical distraction – hands and or feet are away from the driving mechanisms
- Auditory distraction – ears are away from the road

A distraction can also be part of different categories at the same time (WHO, 2011). When analyzing on distraction via roadside advertisements (often referred to as billboards), both visual and cognitive distraction take place (Stelling-Konczak & Hagenzieker, 2012). Distraction due to roadside advertisements has been analyzed by Hinton et al. (2022). She proposes a framework to gain insight in how driver behaviour interacts with roadside advertising: The driver behaviour and roadside advertising conceptual framework (DBRA framework) (Hinton et al., 2022). The allocation of attention is the focal point of the framework and can be affected by the characteristics of roadside advertising signs. Content, such as text, graphics, photos, multiple colors as well as the placement digital or static nature, as well as the level of brightness are all characteristics to be considered when designing (D)OOH-advertisements (Oviedo-Trespalacios et al., 2019; Marciano, 2020). And thus form a potential for driver distraction.

In their literature overview study, Vlakveld and Helman (2018) use the SEEV framework (Saliency, Effort, Expectancy, Value (Wickens, 2021)). For attracting the driver's attention, the factor saliency contains the presence of movement, the lighting and contrast with background and the transitions of advertisements. The effort factor explains how demanding a roadside advertisement is and therefore is responsible for maintaining the attention. How much text, different fonts or colors, the size of the advertisement play a part in this factor. For expectancy, the driver's expectations are important. For example, when a driver expects a screen to contain driving related information, and it turns out to be an advertisement, this can

hold the attention longer than the driver would expect beforehand. The factor value refers to the priorities of the driver; how relevant something is for them to complete a task (Vlakveld & Helman, 2018).

1.1.2. (D)OOH advertising

Along every type of road infrastructure, there are advertising objects in place to target road users as audience. There are different types of objects. Well-known are the billboards: large, often LED-lighted screens, placed on raised level poles. But, as Hinton et al. (2024, p. 2) states: *“Any sign within the road corridor that derives a profit or benefit from advertising a message may be considered a roadside advertising sign.”* In cities, advertising along bus shelters, advertising on roundabouts, or advertising on lampposts are common (CROW, 2017a). Outside cities, on roadways and highways (or in Dutch so-called ‘Stroomwegen’), one can often find (digital) billboards, banners on buildings or in grasslands and VMS (variable message signs) (CROW, 2017a). The information and placement of VMS are governmental regulated and therefore experience less tension between the road agencies and advertisement industry than the placement of commercial advertisements (CROW, 2017b). Banners on buildings and grasslands are often on-premise signs and/or local advertisements, whereas static and digital billboard are often part of (digital) out-of-home campaigns (CROW, 2017a).

Outdoor advertising, or (digital) out-of-home advertising ((D)OOH advertising) are a popular way of advertising for companies and governments (Wilson, 2022). Roadside advertising plays a key role in (D)OOH advertising. Roadside advertising next to highways and roadways plays a predominant role in this. It is proven to be effective and popular for companies to reach a large amount of people (Cronin, 2006; Wilson, 2022). Due to increasing traffic (CBS, 2024), the audience that can be reached grows too. Contrary to online advertising, (D)OOH advertising often can’t be ignored, it is always present. Especially with the digital billboards, there can be advertised very efficiently, it is for example possible to show an advertisement for an ice cream brand automatically when it is warmer than a predetermined temperature (Bauer & Lasinger, 2014). This dynamic aspect makes (D)OOH advertising a popular form of traditional media (Wilson, 2022).

Wilson (2022) defines OOH advertising as *“commercially available and physically rentable assets situated outside the home in both public and commercial places”*. Large billboards along highways and roadways are property and under management of large (D)OOH companies. Large (D)OOH companies active in the Netherlands are for example Ocean Outdoor, Hillenaar/Global and Bereik B.V. (Ocean Outdoor; Hillenaar Outdoor; Bereik, 2025). These companies are leaseholders and rent a piece of land from municipalities or private owners and place a billboard there. They are (in most cases) not the owner of the land, but they are the owner of the billboard. These (D)OOH companies earn money by renting the screen for companies that want to advertise. On the other hand, the owner of the land earns money by collecting the rent, which often is the municipality, province or a private owner. In addition, the municipality where such a billboard is located in, earns money by advertising taxes (Ondernemersplein, 2024). This illustrates that there are multiple interests in play in the world of roadside advertising.

Roadside advertising does have the potential to impact driver safety, potentially contributing to driver distraction (Megías et al., 2011). In essence, advertisements are there to gain attention, while drivers on the road should also have their attention on the driving task.. Road agencies are responsible for the safety of their road users, and advertisement companies want to gain attention from the same road users. This creates tension between the road agency and advertising companies. Driving is a task that demands attention from the user, and mistakes due to distraction while driving can cause crashes and lead to accidents and ultimately, fatalities. Governments highly value road safety and therefore, use policies to prevent driver distraction. To reduce distracted driving, there can be taken several measures, divided over three categories. Measures that are oriented on people (the driver), oriented on the vehicle and third, infrastructure-oriented measures (Vlakveld, 2018). Since distraction by roadside objects and buildings is

involuntary, it makes sense that policies are focused on infrastructure-oriented measures (Stelling-Konczak & Hagenzieker, 2012).

1.1.3. Policy guidelines for assessment framework

To mitigate potential negative safety effects of (D)OOH advertising, there are advisory policy guidelines in place, which are laid down in a framework from the Department of Waterways and Public Works (in Dutch: Rijkswaterstaat) (Rijkswaterstaat, 2019). This is the main road agency in the Netherlands. It is their responsibility that highways and roadways and their road users are safe (Rijkswaterstaat, 2019). The guidelines are enclosed in a decision-making framework. This *'Dutch policy guidelines for assessment framework'* currently considers eight criteria, of which three are 'barrier criteria' and five are 'consideration criteria' (Rijkswaterstaat, 2019). The three barrier criteria are as follows: the distance to the road, the dynamic nature of roadside advertising and the (il)luminance. The five consideration criteria are: the location in longitudinal direction; the design must not resemble driving information signs; viewing time and maintaining attention; objects must not mislead; and objects must fit in the landscape and spatial quality (Rijkswaterstaat, 2019). The assessment framework was first constructed in 2011 and last revised in 2019.

For the placement of a roadside advertising object, a (D)OOH company must first acquire a permit. Licensing authorities, such as Rijkswaterstaat, municipalities or provinces decide whether a roadside advertising object can be permitted. The advisory guidelines in this framework should help these decision-makers to assess whether a permit for a roadside (advertising) object should be granted. This framework applies for all objects and buildings along Dutch highways, with an emphasis on (digital) roadside advertising (Rijkswaterstaat, 2019). However, since these are just advisory guidelines, the jurisdiction is not strict. In addition, jurisdiction depends on the location where a roadside advertising object should come. There are three categories: first, placement within the management area of Rijkswaterstaat. Here, Rijkswaterstaat is responsible and can strictly follow their own guidelines. Secondly, on motorway service areas there are specific guidelines in place, and the guidelines in the framework are additional. However, the third possible location is anywhere outside the management area or motorway service area, thus on land of the municipality or provinces (Rijkswaterstaat, 2019). As mentioned earlier, it is in this category where there is a business case for both the advertising company as well as the licensing authority. It is therefore no surprise that most of the roadside advertising is placed here. Thus, most of the time, it is the municipality that decides over the permit application for a roadside advertising object to be placed. But the framework is advisory, municipalities are only advised and asked by Rijkswaterstaat to have a critical look at a permit application, by using the guidelines in their assessment framework. Municipalities do often comply, but there is no jurisdiction for Rijkswaterstaat if a municipality were to decide to grant permit for a billboard that does not follow the guidelines (Rijkswaterstaat, 2019).

In a literature overview study, Boets et al. (2018) analyzed 20 countries on their guidelines and regulations. All countries were member of the CEDR (Conference of European Directors of Roads), except for Australia and New Zealand. The majority of countries has guidelines in place, where placement criteria are more often covered than design criteria (Boets et al., 2018). However, they conclude that the level of detail varies greatly between the studied countries. In an overview study by Wachtel (2009), there is concluded that all of the studied countries use solid theoretical research as underpinning for their guidelines. In a paper by Rempel et al. (2014), five principles for developing regulations for display advertising are presented. They state that guidelines should be based on evidence, however, they also acknowledge the (lack of) availability of conclusive research.

1.1.3.1. Safe System approach

The presence of policy guidelines does fit in the vision of a Safe System approach. Safe System approaches, as Vision Zero and Sustainable Safety, state that crashes should be prevented as much as

possible (Weijermars & Wegman, 2011). This vision is a leading principle in the Netherlands for developing road safety policies; every potential risk that road users are exposed to, should be mitigated. Roadside advertising cause distraction of drivers. Distracted drivers in their return cause crashes, which makes that the risk for safety impact of drivers by roadside advertising is present. This stresses the need for mitigation policies, as the Dutch framework for roadside objects. As roadside advertising is intertwined into the road system, the prevention of crashes due to driver distraction is a complex problem. It is unknown to what extent roadside advertising contributes to crash occurrence, as there are many factors in play in the road system. At the same time, many stakeholders are present in the system, e.g. Rijkswaterstaat, advertising companies, governmental bodies, private landowners and drivers. Rijkswaterstaat is responsible for the drafting of the guidelines and thus acts as a policymaker in this system (Rijkswaterstaat, 2019). The focus of this thesis is on the policymaking aspect of the guidance document, as they're the one that are responsible for the mitigation by guidance, which is an important aspect in both Vision Zero and Sustainable Safety.

1.1.4. Safety impact of driver distraction by roadside advertising

The potential for driver distraction by roadside advertising is present, but the relation and influence on traffic safety is difficult to assess (Oviedo-Trespalacios et al., 2019). Roadside advertising is designed with the intention to attract the driver's attention, and literature shows that this happens. There is scientific consensus when it comes to lateral control, or lane keeping, nearby billboards. Billboards do, be it slightly, negatively influence the lateral control of drivers, due to distraction (Edquist et al., 2011; Vlakveld & Helman, 2018; Young et al., 2009). Also, the headway distance that drivers were able to keep on roads with billboards is a factor that could indicate driver distraction. Milloy and Caird (2011) found that this differs significantly between roads with and without these billboards. On the other hand, Young and Mahfoud (2007) did not find a difference between roads with any type of billboards and roads without.

The question remains how problematic this is, is there a link between crash occurrence and roadside advertising? For determining road safety and crash risk, crash data analysis is widely the most common type of study to conduct, however, it brings implications with it (Oviedo-Trespalacios et al., 2019). Crash numbers are often low, also due to the underreporting of low severity crashes, as a result, previous studies showed inconclusive results (Oviedo-Trespalacios et al., 2019).

There are a few studies that have analyzed historical crash data in order to test the relation between roadside advertising and crash risk. However, the results are inconclusive and not unanimous. In a study in New Mexico, Tantala and Tantala (2010) did not find any (significant) difference while analyzing crash data. There were 17 billboards in Albuquerque, NM, analyzed on both up- and downstream crashes for over seven years, but no relation with crash risk was found. Two Canadian studies in Toronto, nine years apart from each other, did not find differences in their before-and-after study (Smiley et al., 2005; Izadpanah et al., 2014). Contrary, an American study by Sisiopiku et al. (2015) found a statistically significant increase of 29% in crash occurrence for a set of billboards in Alabama. For each of these billboards, a specific 'influence zone' determined; a range within the billboard could have potential impact on the driver. Although the overall result was significant, on the individual level, the results were mixed.

These four mentioned studies were all conducted on digital billboards. Furthermore, there is a Greece before-and-after study by Yannis et al. (2013). This study did not specify whether they analyzed static or dynamic advertisements. In this study, specific road segments with billboard in place were taken, but contrary to Sisiopiku et al. (2015), there was no specific range per billboard. No impact on crash risk was found in this before-and-after study. An Israeli study by Gitelman et al. (2019) had the opportunity to analyze the presence, absence and presence of billboards along the Avalon Highway. Due to a ban on roadside advertisements in 2008, the effect could be measured. After one and a half year, mid 2009, the billboards were permitted and placed again. As road segment, the whole of the Avalon Highway was

taken. The removal resulted in a 30-40% decrease in injury crashes, while the restoring the billboards showed an increase of 40-50% again. Both effects were statistically significant (Gitelman et al., 2019). This finding is relevant and indicates impairment of road safety. However, as (D)OOH advertising is a rapidly changing innovation, more evidence is desired, especially with the rise of digital billboards (Wilson, 2022)

In the Netherlands, there is only one small before-and-after study done on crash data with regard to (digital) billboards (Wools et al., 2017). This is a small study, as part of a graduation assignment. In this study, three billboards along Dutch highways were investigated on crash count in the vicinity of the billboard. For one of three billboards, there was an effect of more crashes observed, however, the numbers are very, very small. It is difficult to draw conclusions from this study.

It is hard to obtain statistically significant results due to the fact that crashes are rare events (Vlakveld & Helman, 2018). Because crashes are rare events, it is important to analyze data over a long period of time, as Tantala and Tantala (2010) did, or use long segments of roads, like Yannis et al. (2013), preferably with a control group, as done in the before-and-after study by Gitelman et al. (2019). Even though, it remains hard to obtain conclusive results from crash data analysis, and while road agencies and governments prefer to use clear and defensible results from literature to draw up guidelines, it leaves them with using other indicators (Oviedo-Trespalacios et al., 2019). Therefore, indicators of road safety like gaze behaviour, headway distance and lateral control, are often taken into account when assessing the impact of roadside advertising (Vlakveld & Helman, 2018; Oviedo-Trespalacios et al., 2019).

1.2. Knowledge gaps

There is consensus that roadside advertising along highways have a potential negative influence on the safety of the road users of those highways (Megías et al., 2011; Oviedo-Trespalacios et al., 2019). Therefore, there are guidelines in place to mitigate potential safety impacts. There is consensus that guidelines and legislation for roadside advertising should be theoretically grounded (Rempel et al., 2014). Some of the criteria mentioned in the Dutch assessment framework are grounded by literature, but there are also criteria that rely on expert judgements, rather than scientific evidence. Although, this is not problematic, there is room for complementing the evidence base. Also, the current Dutch assessment framework is last revised in 2019. Now, six years later, there is increased technology, and the out-of-home advertisement industry is changing constantly (Wilson, 2022). This motivates the need for an updated overview of current knowledge of roadside advertising and its potential impact on road safety.

Most international best practices also have their guidelines grounded by scientific research (Wachtel, 2009). However, there is no insight in how best practices across different countries align. It is unknown whether they use the same evidence-base to build their guidelines and legislation on. In 2018, there is one comparative study done by Boets et al. (2018). This study concluded that the level of detail varies across the different studied countries. It leaves space for aligning the Dutch framework with the best practices currently in effect, especially seven years after the study of Boets et al. (2018).

In existing literature, there is no conclusive evidence on the level of safety impact that roadside advertising has on the drivers on highways. There are a handful of studies conducted that use crash data analysis by the form of a before-and-after study, but all results are non-significant, except for Gitelman et al. (2019). For Dutch highways, there is no insight in the extent of safety impact by roadside advertising. Due to methodological implications as insufficient data, many confounding factors and the rare nature of crashes, it is hard to obtain significant results (SWOV, 2012; Oviedo-Trespalacios et al., 2019). However, risk figures obtained from crash data analysis are often considered as golden standard for assessing the impact on road safety (Oviedo-Trespalacios et al., 2019). Industry also asks for empirical evidence, as the lack of empirical evidence leaves room for discussion about the role that roadside advertising plays in road safety (Oviedo-Trespalacios et al., 2019).

1.2.1. Research objectives

The aim of this research is to gain insight in what is needed to update policy guidelines regarding roadside advertisements along highways and motorways. The Dutch policy guidelines are built upon an evidence base which was last revised in 2019. This research aims to strengthen this evidence base. Another research objective is to provide an overview of policy guidelines of other countries, so that there is a small, but concise database on best practices, where policy makers can learn from. Third, the aim is to gain insight into which extent roadside advertising has an influence on road safety. For the Netherlands, these numbers are unknown. When this research could provide these insights on what is needed to revise policy guidelines, the policy guidelines could be shaped accordingly.

1.3. Research questions

1.3.1. Main research question

What are the differences between current evidence-based insights and the Dutch policy framework about placement of roadside advertising objects along (high)ways?

This research question is chosen because it aims for a better understanding of the current knowledge on roadside advertising and the policy implications. The evidence in this thesis will consist of three sources, being recent literature, international best practices, and the results of a crash data analysis, conducted on Dutch state roads. When identifying the insights from these evidence sources, there is structured knowledge base, which ultimately could be used for revising the current Dutch assessment framework. When answering the question, policy recommendations can be provided, if found to be relevant. It also addresses the geographical knowledge gap for the Netherlands. Although the policy guidelines for assessment framework by Rijkswaterstaat applies for all objects and buildings along highways, e.g. also wind turbines, the emphasis in this thesis is on roadside advertising.

1.3.2. Sub questions

1 *What are the differences between recent literature and the criteria that are currently in the Dutch guidelines for object alongside (high)ways?*

There are currently eight advisory guidelines in the Dutch guidelines for assessment framework for objects alongside (high)ways. These guidelines can be used by the licensing authority for assessing objects. Licensing authorities are for example: Department of Waterways and Public Works, municipalities, provinces and/or other authorities. Three out of eight guidelines are so-called ‘barrier criteria’, which are classified as more important and leave little to no room for interpretation by the licensing authority. On the other hand, there are five ‘consideration criteria’. These are more arbitrary, but also important to assess the potential distraction of a roadside advertisement object.

Most of the guidelines are underpinned with literature. The assessment framework was first composed in 2011 and last revised in 2019 (Rijkswaterstaat, 2019). The question rises whether the findings in these sources are still best-in-class. Is the evidence-base that is used in the current framework still applicable?

2 *What are the differences between the criteria and thresholds used in policy guidelines and regulation frameworks from other countries and the Dutch guidelines for object alongside (high)ways?*

To gain a better understanding of how to cope with potential driver distraction of roadside advertisements, current regulatory frameworks of other countries are analyzed. First, a set of relevant countries to compare with should be identified. To come to a selection for which countries can be used as comparison, data needs to be found on road safety. Both risk figures as well as infrastructure rating can be used to determine a set of countries that are similar to the Netherlands. Besides, cultural similarities are included as selection criteria and there needs to be guidelines and/or legislation in place in these countries. Once a set of countries is determined, preferably seven to ten countries, the frameworks about roadside advertisement objects of these countries can be analyzed. By answering this sub-question, it is possible to gain an overview of guidelines and regulations in other countries. This way, there can be learned from these best practices in other countries. There can be differences found in the content of the frameworks of other countries.

3 *To what extent do digital billboards influence the crash risk on Dutch motorways?*

For assessing road safety, crash data is often a key performance indicator. However, it is hard to study road safety in relation to roadside advertising by the use of crash data analysis. As mentioned in the literature review, there are only a few studies that did use crash data analysis. For the Netherlands, only a small study by Wools et al. (2017) is conducted, so the knowledge gap is quite big. For this research question, only digital billboards are investigated. This is chosen because other forms of roadside advertising, like VMS and on-premise signs are a little less applicable. The messages and use of VMS are for example government regulated, and therefore the tension between road agencies and advertisement companies is not in place. Grassland signs and on-premise signs are often local advertisements, placed by independent parties, while digital billboards are often part of a (D)OOH company. It is therefore easier to obtain data on digital billboards from a large (D)OOH company.

1.4. Research contribution

This research aims to contribute to this field of science by updating the knowledge base for driver distraction and roadside advertising. By evaluating and updating the evidence base in a structured way, this systematics could be used in further studies for evaluating other policies. Another gap this thesis aims to fill is to contribute to the (lack of) quantitative research. When a model can be composed that can assess crash risk imposed by roadside advertising billboards, this would be of high scientific relevance. However, if not, this research could also provide further insight in which difficulties cause that this quantitative research is not practicable.

Regarding societal contribution, this research aims to provide recommendations for updating the current assessment framework used by governments. By the hand of updated information on scientific knowledge and best practices of other well-performing countries, policymakers are able to use this to make better informed decisions on placement of roadside advertising.

1.5. Scope

There are two aspects of a policy framework, on one hand it is about *how* the assessment framework is being used, what is its jurisdiction? On the other hand, it is about what is *in* the assessment framework, what are the guidelines and why are they important? In this thesis, there will be focused on the latter aspect, the content of the assessment framework. Another demarcation is that, although the policy guidelines also apply for example for wind turbines and art objects, the emphasis of this thesis report is on roadside advertising. More specific, static and digital (dynamic) billboards are the main type of roadside advertising during this thesis.

1.6. Reading guide

This chapter provided background information to introduce the different topics covered by this thesis. Also, the knowledge gap, research questions, research contribution and the scope of this thesis are discussed. In chapter 2, the different methodologies are presented that are used to answer the research questions. Chapter 3, 4 and 5 presents the results of these methodologies, whereafter this will be discussed in chapter 6. Also in this last chapter, the conclusion, practical recommendations as well as recommendations for further research are presented.

2. Methodology

2.1. Literature review

The guidelines in the current Dutch assessment framework are built on a scientific fundament. During the literature review of this thesis, this scientific fundament will be reviewed and used as starting point for identifying relevant recent literature. This new, recent literature is structurally reviewed with the objective to strengthen the evidence-base that can be used in shaping revised policy guidelines.

2.1.1. Data collection

A literature review will be conducted using the snowballing technique, more specific forward snowballing, which is helpful to identify relevant literature. As the literature review of this thesis builds upon the already available knowledge base that is used in the Dutch framework, snowballing was chosen as appropriate method. Snowballing can either be backward or forward snowballing, where backward snowballing makes use of the references of a scientific paper and forward snowballing makes use of the citations. To start with the snowballing procedure, a starting paper or set of papers is needed. This can for example come from a search string, however, in the literature review of this thesis, the starting set is derived from the Dutch assessment framework. The goal of this literature review is twofold: to identify the current knowledge in the field of roadside advertising with regard to distracted driving *and* to compare this with what is covered in the current Dutch framework. Is the evidence-base that is used in the current framework still applicable?

The Dutch assessment framework is last revised in 2019, which is six years ago. By taking the literature used in the Dutch assessment framework as starting set, the base of evidence (up to 2019) is taken and will be updated through the literature review. With this updated evidence base, there can be assessed whether there are implications for the Dutch guidelines.

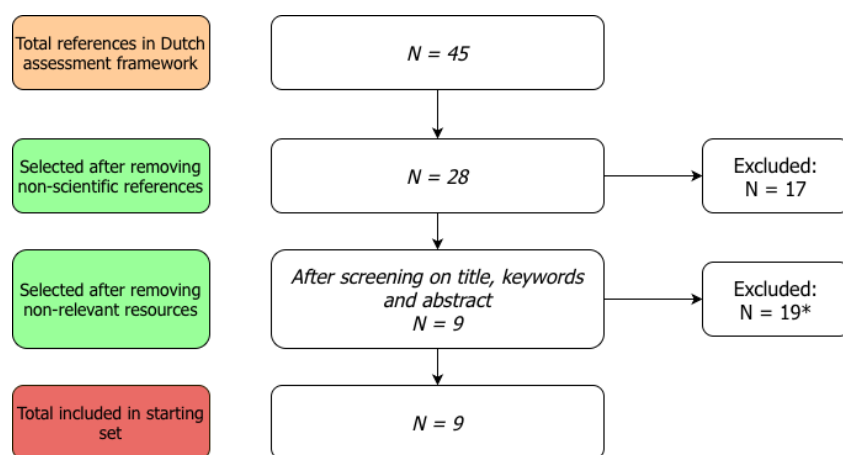


Figure 1: Identifying the starting set

The starting set is based on the literature used in the current Dutch framework, however, not every reference in the framework is relevant. In total, the Dutch framework uses 45 references. Some were scientific articles, findable on scientific databases Scopus and Google Scholar. But others were not findable on Scopus and Google Scholar, these were for example websites or policy documents. These are considered as non-scientific. Some sources were otherwise not relevant to include, due to non-road safety related topics. Although, non-scientific sources can undeniably be helpful in strengthening and reasoning of policy guidelines, conducting a structural snowballing analysis is not practical with these sources, as they are not included in widely adopted databases. Seventeen references were non-scientific and another 18 were found to be not relevant as starting point for a literature review on road safety and

roadside advertising. However, 19 references were excluded in this step. This is because one reference (Birth, 2008) was included in the reference list of Rijkswaterstaat (2019) but never mentioned in text. This left a starting set of 9 scientific articles, as displayed in Figure 1.

The included scientific sources in the starting set are structured in Table 1 below. It can be seen that all scientific literature is used for underpinning barrier criteria 2.1 and 2.2.

Table 1: Included literature from Dutch assessment framework in starting set

Author(s)	Year	Journal	Citations after 2019	Type	Place in Dutch assessment framework
Beijer et al.	2004	Transportation Research Record: Journal of the Transportation Research Board	33	Naturalistic driving study	Criterion 2.1 (Distance from roadway) & 2.2 (Changeable images)
Crundall et al.	2006	Accident Analysis & Prevention	50	Eye-tracking on video simulation	Criterion 2.1 (Distance from roadway)
Gitelman et al.	2019	Traffic Injury Prevention	16	Crash data analysis	Criterion 2.2 (Changeable images)
Mollu et al.	2018	Transportation Research Part F: Traffic Psychology and Behaviour	25	Driving simulator study	Criterion 2.2 (Changeable images)
Stavrinos et al.	2016	Transportation Research Part F: Traffic Psychology and Behaviour	33	Driving simulator study	Criterion 2.2 (Changeable images)
Young et al.	2017	Applied Ergonomics	19	Naturalistic driving study	Criterion 2.2 (Changeable images)
Belyusar et al.	2016	Accident Analysis & Prevention	34	Naturalistic driving study	Criterion 2.2 (Changeable images)
Molino et al.	2009	-	10	Literature review	Criterion 2.2 (Changeable images)
Vlakveld & Helman	2018	-	5	Literature review	Criterion 2.2 (Changeable images)

In Figure 2, the snowballing procedure is shown. Seven of the included articles in the starting set were available and thus searched via Scopus, where their citations were found. Two others (Molino et al., 2009; Vlakveld & Helman, 2018) were searched via Google Scholar. A filter was set from citing articles published from 2019 to 2025, in order to update the evidence base from 2019, which was the release date

of the Dutch assessment framework. After consequently the title, abstract and place of citation in text was analyzed per article, a full read was done on an article that was found to be relevant.

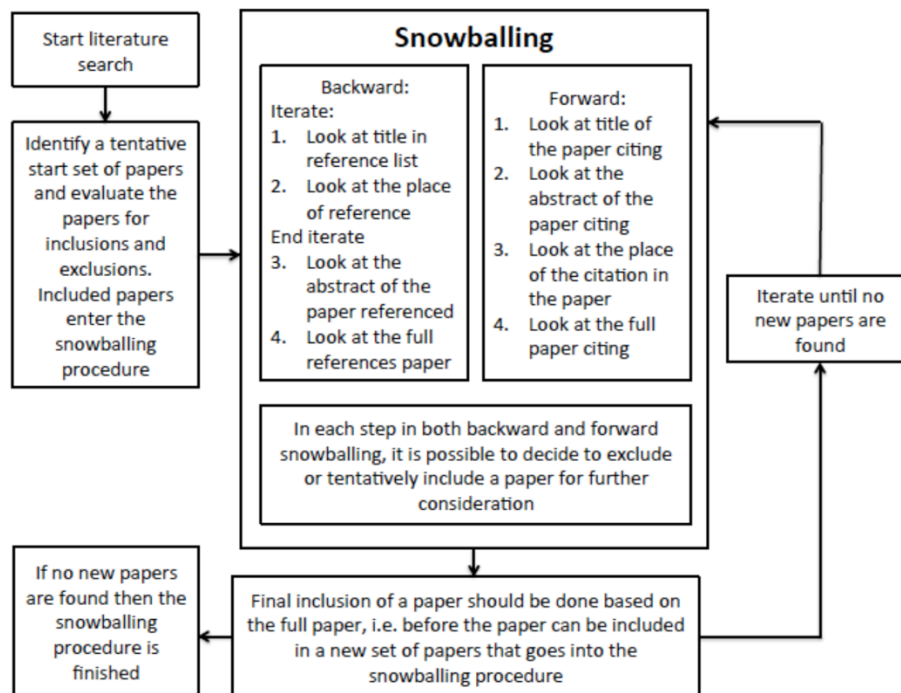


Figure 2: Snowballing procedure (Wohlin, 2014)

The amount of citing articles was 225, whereafter the duplicates (82) were removed, this left 143 articles to be scanned by title. 102 articles were not found to be relevant after scanning the title. After scanning the abstract, another 11 articles were removed out of the procedure. Consequently, the remaining 30 articles were scanned on the place in text where the citation was used. Two other articles were removed after this screening. This left 28 articles to be fully read. Two articles were found to be a previous version of another included article. These were Sheykhfard & Haghghi (2020) and Yang et al. (2020), respectively corresponding to Sheykhfard et al. (2024) and Yang et al. (2024). Three other articles were removed due to being not relevant. One article, by Meuleners et al. (2020) was included after being cited by 10 already included articles. This resulted in 24 articles to be used in the literature review. An extensive overview of the 24 reviewed articles is provided in Appendix A.

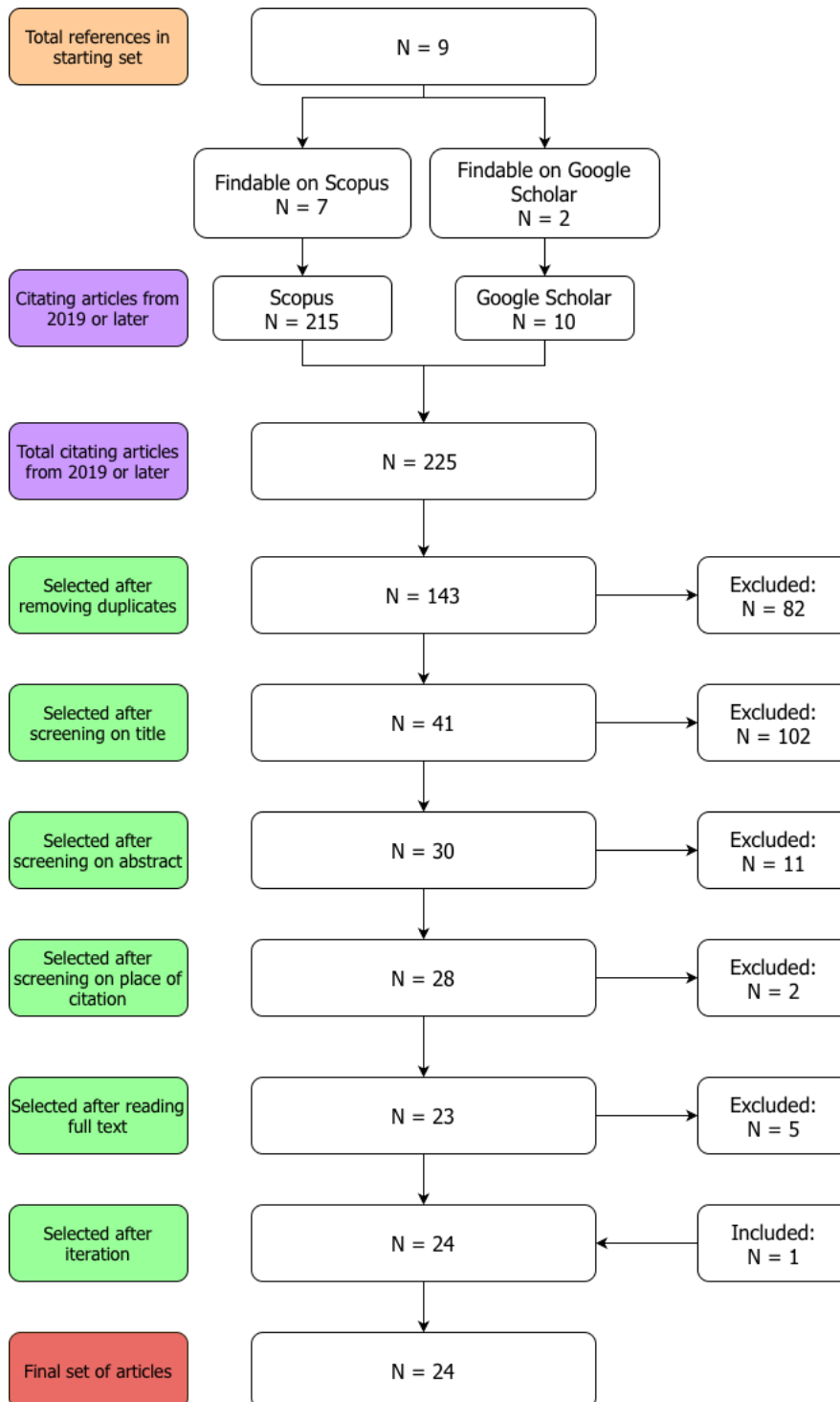


Figure 3: Screening procedure

2.1.2. Data analysis

After the snowballing procedure is finished, the papers to be included in the literature review are identified and can be analyzed thoroughly. This again is done per criteria used in the Dutch assessment framework, so the results are structured. There will be table used in where a distinction is made between confirmative new literature and contradictory new literature, compared to the current Dutch framework. This way the evidence base can be updated accordingly with all new findings.

2.2. Comparative analysis of best practices

To gain a better understanding of how to cope with potential driver distraction of roadside advertisements, the best practices of other countries will be analyzed. This way, an overview is presented of existing guidelines and legislation on roadside advertising.

2.2.1. Data collection

To come to a selection of relevant countries to analyze, a few criteria will be used to assess whether a country is relevant to analyze in comparison to the Netherlands. Eventually, the goal of this comparative analysis is to identify new information and best practices that can be used to improve the Dutch guidelines regarding roadside advertisements.

2.2.1.1. Selection of countries

To come to a selection of countries that can be analyzed on guidelines on roadside advertising, four criteria are used:

1. Road safety performance (better or similar to the Netherlands)
2. Road quality performance (better or similar to the Netherlands)
3. Cultural similarity (with regard to the Netherlands)
4. Accessible official information

The first criterium is how countries score on road safety performance. Road safety can be measured in many different ways, by many different indicators. SUNflower is a 2002 study that compared three well-performing countries in terms of road safety and searched for underlying (policy) elements and indicators to measure the performance of these countries (Koornstra et al., 2002; Wegman & Oppe, 2010). The countries are Sweden (S), United Kingdom (U), and the Netherlands (N). When looking at a road safety target pyramid used in the SUNflower approach, adapted from the LTSA (2000), there are multiple layers used to identify the level of road safety in a region or country.

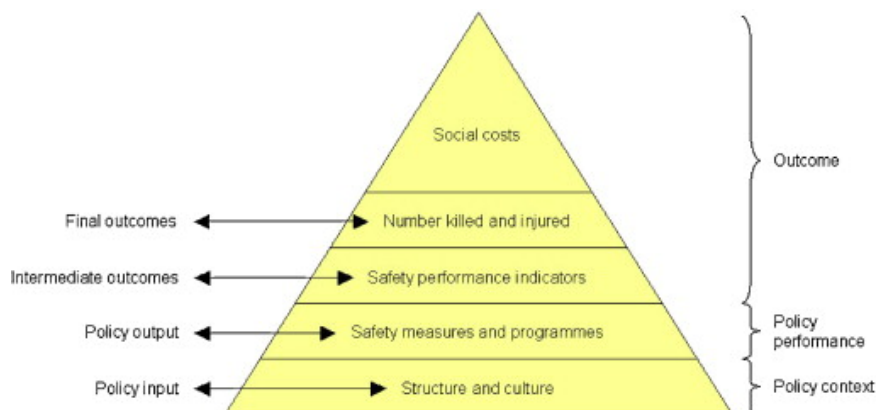


Figure 4: Road safety target pyramid (Koornstra et al., 2002)

The foundation is the structure and culture of a country, whereafter the safety measures and programs of a country are the next layer. This is the layer where we want to learn more about in this sub-question, we want to know what is in the best practices from other countries we can learn from. The pyramid continues with the three top layers that focuses on the outcome of the policy context and the policy. The outcome is measured in three different type indicators. First, the safety performance indicators, or so-called intermediate outcome. For example, the Baseline project, which was funded by the European Commission, identified eight different key performance indicators, varying from speeding to seatbelt use, and from alcohol-use to vehicle safety (European Commission, 2023). The next layer in the pyramid

contains the number of killed and injured people, or the so-called final outcome. They also include the societal costs in the final layer, resulting from these fatalities and injuries.

For the selection of countries in the research of this thesis, three factors are used as selection indicators: annual crashes (final outcome), quality of road infrastructure (safety performance indicator) and cultural similarities (with regards to the Netherlands). To keep a selection process pragmatic, these three seem suitable. For safety performance indicators, only quality of road infrastructure is chosen. As road advertisement regulations are about the placement and content of roadside advertising, this has direct impact on the building environment along the roadway.

There are different databases that store information on annual crashes, the European Road Safety Observatory (ERSO) uses the CARE database from the European Commission, which contains high-aggregated data on road fatalities (European Commission, 2025; Yannis et al., 2017). Another commonly used database is from the Organization for Economic Co-operation and Development (OECD). The International Transport Forum (ITF) use this data in their safety report (ITF, 2024). Furthermore, data from the European Transport Safety Council (ETSC) is used in their Performance Index (PIN) report (ETSC, 2025). These three data-sources are used to identify countries which are better or similar performing than the Netherlands, considering the annual crashes indicator. For the indicator quality of road infrastructure, data from the World Economic Forum (WEF) is used (WEF, 2019). The last indicator, culture, is more arbitrary. Here, the focus is on if the identified countries are found to be similar to the Netherlands. For example, EU countries or other countries that are considered western. One fourth criterium is more of a limitation, but nonetheless important, there need to be guidelines and/or legislation in place in the identified countries.

For risk indicator, both annual crashes per (million) inhabitants or annual crashes per vehicle kilometers travelled can be used. This figure shows the risk of a citizen being killed in traffic and can help within a country to compare different causes of death, and to compare countries with a similar level of motorization. In most countries, this figure is often available (ITF, 2024), wherefore it is a pragmatic figure to use in determining a selection of countries. The other risk figure uses vehicle kilometers travelled as denominator. This is considered as better risk indicator to assess the risk of the road network (ITF, 2024) and to compare between countries.

2.2.1.2. Retrieving the official information

After a set of countries is identified, the guidelines and/or legislation of these countries should be retrieved. This information can often be found on official government websites, the Dutch assessment framework is for example on the Rijkswaterstaat webpage (Rijkswaterstaat, 2019). However, there might also be additional or indirect sources of information, for example awareness campaigns (Rejali et al., 2024). The search process is done by AI. This is done because AI nowadays can quickly browse the web and since most official information is in the language of the respective country, AI can read this effortlessly. The goal of this AI search is not per se to directly retrieve the guidelines and/or legislation as a readily available document, but to get an overview of webpages of where to get this official information. However, if the AI tool is able to directly answer with the right document(s) of a country, this would be extra helpful.

There are multiple AI tools that can be used, where ChatGPT 5 (OpenAI) and Copilot GPT-5 (Microsoft) are used in this thesis for this purpose. Both AI tools were tested and asked the same questions. ChatGPT 5 was able to respond more accurately compared to Copilot GPT-5. It was therefore ultimately decided to conduct the search process with ChatGPT 5. The prompts that were used are the following:

A first prompt was to guide the AI tool in the right direction and at the same time to check whether it understands the objective:

“In the Netherlands, there are guidelines in place regarding the placement of roadside advertising objects along highways. Could you provide me the official government information document on this topic?”

As a result, ChatGPT 5 answers with a link to the PDF document on the Rijkswaterstaat webpage (Rijkswaterstaat, 2019). After this prompt had the successful result, a second prompt was asked to expand this search for the countries this research is interested in:

*“Now, can you provide me the same or highly similar information from the following countries:
Country A
Country B
Country C
...
Country X”*

Now, there are webpages identified where the official information can potentially be found. These webpages and documents are often in the respective language, so first they are translated. This is for both webpages as well as pdf documents possible via Google Translate (Google, 2025). After translation, the webpages and documents will be screened on the official information.

2.2.2. Data analysis

After the guidelines and/or legislations of multiple countries are found, they will be structurally analyzed. The analysis will be done by the hand of the following topics:

Table 2: Reviewed topics in foreign guidance documents

Placement	Dwell time	Sign type	Illuminance	Sign content	Landscape and Spatial quality
Meters outside of the roadway Viewing angle Intersections Curved roads Blocking vision Speed Turbulence zone Clutter	Transitions		Rural vs urban Daytime and nighttime Crash modus	Color Text Images and video Emotionally loaded content Level of expectancy Size Resemble to traffic information	

This list is constructed by the hand of the topics already covered in the Dutch assessment framework (Rijkswaterstaat, 2019), together with topics covered in the literature overview of Oviedo-Trespalacios et al. (2019). The topics are chosen carefully to identify thresholds and insights on both disaggregated level (subtopics) as well as the aggregated level. The topics placement, dwell time, illuminance and sign content are divided into subtopics, as can be seen in in Table 2. Sign type and landscape and spatial quality are also carefully reviewed, but as the international best practices did not specify much on these topics, no breakdown into subtopics is made.

Per topic, there will be noted what is written about it in the guidelines and/or legislation of other countries. There will also be per topic noted how the analyzed guidelines and/or legislations compare to the Netherlands. When other countries use scientific sources to underpin their guidelines and/or legislations, as done in the Dutch assessment framework, this will be also noted.

2.3. Crash data analysis

Existing studies on crash data analysis are shown to be inconclusive on assessing the safety impact on road users. Due to methodological implications, it is difficult to obtain significant results. The data analysis in this thesis aims to gain more insight on potential safety impact of digital billboards and to build upon previous conducted crash data analysis studies in order to add to the knowledge gap. The data analysis in this thesis will be a small, pragmatic, before-and-after analysis with control group on crash data. To conduct a before-and-after analysis, two data sources are needed. First, crash data, and secondly, data on roadside advertising. In this analysis, the scope is demarcated to digital billboards only.

2.3.1. Data collection

To check for differences in number of road crashes related to the placement or digitizing of a billboard, a before-and-after analysis is commonly chosen as a suitable method (Elvik, 2002). This type of analysis has been used in most previous studies using crash data analysis (Yannis et al., 2013; Izadpanah et al., 2014; Gitelman et al., 2019). Before-and-after analysis builds on the assumption that changes observed in crash numbers at control sites are representative for the changes in crash numbers that would have occurred at the treatment sites, if no treatment (in this case: placement or digitizing) had been implemented. In other words, the control group is assumed to capture crash variations resulting from external factors unrelated to billboards. These factors are called confounding factors, such as temporal trends (regression-to-the-mean bias) or fluctuations in traffic volumes (Elvik, 2002).

To account for these confounding factors, a control group should be large enough (Elvik, 2002). Therefore, as control group, the state road network of the Netherlands *where billboards are not located* is chosen. It is chosen as pragmatic approach, as it is assumed that this displays the general trend of road safety in the Netherlands and accounts for confounding factors well enough. If a more specific control group was chosen, e.g. each billboard with an own specific control group, as done in Yannis et al. (2013), this selection of adequate control group would be precise and difficult to do for every treatment location. It should be noted that in this control group, there *are billboards present*, as the received dataset does not contain data on all billboards in the Netherlands.

For the before-and-after analysis of one single billboard X, the following data is needed:

- The number of crashes that happened in the influence zone of billboard X in the *before period* (Treatment site).
- The number of crashes that happened in the influence zone of billboard X in the *after period* (Treatment site).
- The number of crashes that happened outside the buffer zone of every billboard in the *before period* (Control site).
- The number of crashes that happened outside the buffer zone of every billboard in the *after period* (Control site).

The crash data was retrieved via VIA Software Portal. VIA is an IT-agency that stores data on all sorts of road safety issues (VIA, 2025). Here, the majority of crashes on state roads (i.e. the roads that are in operation by Rijkswaterstaat and thus the roads to which the framework guidelines apply) are stored. The data in this portal is derived from different sources, mainly from police reports, from Rijkswaterstaat data and from MobielSchadeMelden (VIA, 2025). These crashes are displayed on a map, on their exact location where a crash happened. Apart from the location, a crash data point also contains information on the date of the crash, and the outcome of the crash (fatal accident; injury; material damage only). The data could be exported from the VIA Software Portal into a shapefile. A shapefile is a data file format that is used in GIS programs. This is important since most of the analysis is done in ArcGIS Pro 3.3.0. ArcGIS is a data analysis tool to visualize, view, edit and analyze location data (ESRI Nederland, 2025). Both a license

to access the VIA Software Portal and the license to download and use ArcGIS Pro were provided by Movares Smart Urban Engineering, the company at which this thesis is conducted.

The data on digital billboards comes from Ocean Outdoor, a large advertisement company in the Netherlands (Ocean Outdoor, 2025). This means that there are still various billboards, both static and digital, present in the control group. These billboards are for example exploited by other companies than Ocean Outdoor, e.g. Hillenaar or Bereik (Hillenaar Outdoor; Bereik, 2025), as well as all static billboards from Ocean Outdoor are not in the dataset and thus left in the control group. However, this is not seen as problematic for the data analysis, as the potential 'noise' that other billboards or types of roadside advertising create, is considered to be negligible, since the control group is significantly large.

The received dataset contained 61 digital billboards that are either placed or digitized from static to digital between 2014 and 2024. In this data, the exact location in coordinates and the year of placement/digitization of a digital billboard was included. One single billboard in the dataset means one direction of the billboard. So, when a billboard is facing both directions of a highway, this counts as two billboards in the dataset. The data was delivered in pdf format and could be imported into Excel and formatted into a CSV file. This CSV file could in turn be imported into ArcGIS Pro.

2.3.1.1. Data preparation

After both datasets were imported into ArcGIS Pro, the data needs to be prepared for analysis. Concerning the crash data, this was done by splitting the data up per year, so that there is a separate dataset for every year. Regarding the digital billboard data, preparation was a bit more extensive. First, there needs to be determined which digital billboards are eligible for analysis. As both the crash data and the placement/digitization data from the billboards stretches from 2014 to 2024, there would be no point in analyzing billboards placed in 2014 or 2024, since there would be no 'before' or 'after' crash data available for these years. With the same reasoning, it was decided that only digital billboards placed or digitized between 2017 and 2021, are considered in the analysis. For a billboard placed in 2016 for example, only crash data from 2014 and 2015 could be used as 'before' data, which would result in small numbers. In order to maximize this amount of data, 2017-2021 is chosen. This results in a before and after group that contains crash data for *at least* three years. E.g. the 'before' years are 2014-2016 when a billboard intervention is done in 2017 (earliest). In the same way the 'after' years are 2022-2024, when a billboard intervention is done in 2021 (latest).

In the dataset (N=61), there were 21 billboards placed or digitized between 2017 and 2021. These 21 datapoints will be used as treatment site in the before-and-after analysis. For these 21 datapoints, there needs to be an influence zone. This approach is adopted from Izadpanah et al. (2014) and Sisiopiku et al. (2015). An influence zone should be read as the road segment from where a billboard becomes visible for a driver, until it can still have a potential safety impact. This safety impact can also occur when a driver has already driven past a billboard, this is called 'extended engagement' (Hinton et al., 2022). Hinton et al. (2022) mentions that extended engagement occurs when a driver is already driven past the roadside advertising object, so visual distraction is over, but cognitive distraction can still occur due to the object. Within in this predetermined radius, the billboard can thus have potential influence on road safety. So, the influence zone is constructed by adding both the visibility distance as a 'recovery zone'. The visibility distance differs per billboard. One can be seen from more than a kilometer out; another one is placed in a more sheltered position and can only be seen from 300 meters out. To keep the analysis pragmatic, a fixed visibility distance is set to 550 meters. This corresponds with a visibility time of 20 seconds, when a driver is driving at 100km/h. The distance for a recovery zone is set to 150 meters, which corresponds to roughly 5 seconds when driving at 100km/h.

After these radiuses were set for each of the 21 billboards, the exact influence zones were drawn. As mentioned earlier, the screen of a billboard is faced towards one part of the road, so the other road

direction should be excluded from the influence zone. As can be seen in Figure 5, this influence zone is drawn manually, based on both radiuses and the central reservation of the roadway.

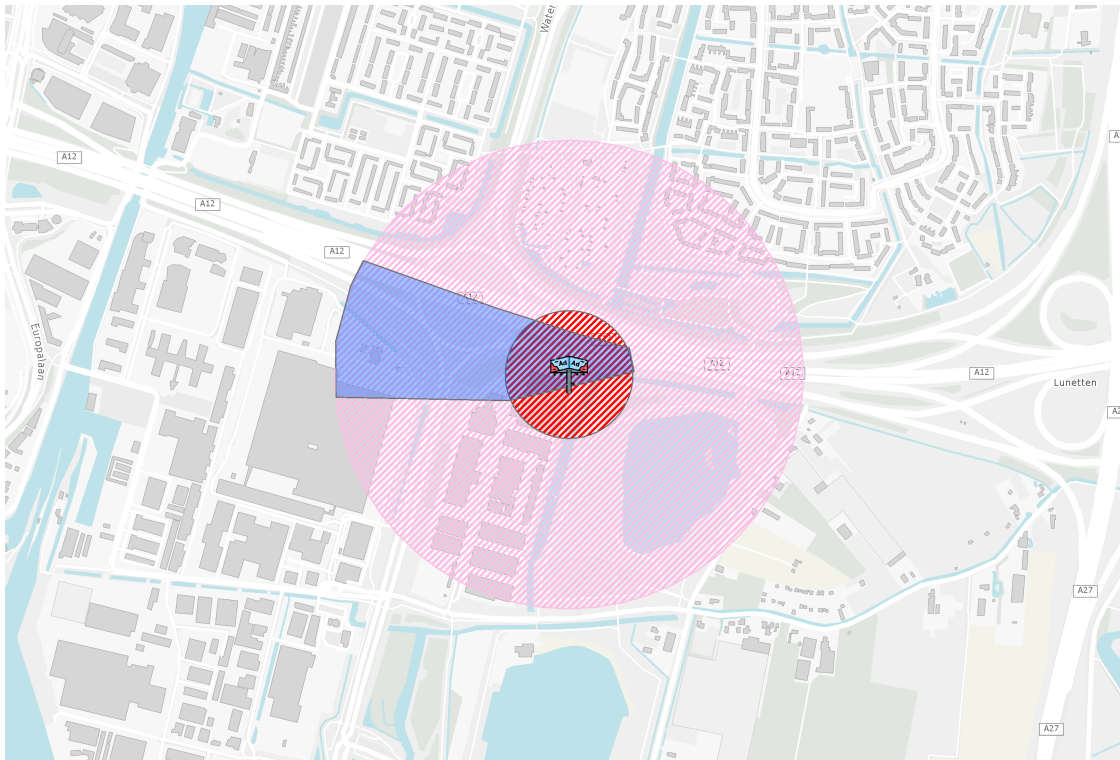


Figure 5: Influence zone billboard

In the figure above, the red shaded circle represents the 150 meters around the billboard and is used for the extended engagement. In this example, the driving direction is from west to east, and the recovery zone, where extended engagement may occur, is on the eastern side of the billboard. The pink shaded area displays the radius of 550 meters, which is used as (pragmatic) visibility distance for each digital billboard in the dataset. The influence zone is constructed based on these two radiuses, marked by the blue area. When looking closely, it can be seen that this area takes the driving direction into account, as it only overlays the carriageways that directs drivers from west to east.

The treatment group, i.e. the crashes within an influence zone can now be determined. These are the green crashes in Figure 6. The control group consists of the whole rest of the state road network, except for every location where a digital billboard in the used dataset is located. Therefore, every billboard in the dataset still has a buffer zone of 550 meters around it, so that the crashes in this area are not included in the control area. This is illustrated in Figure 6. Beside the billboard in the middle, the billboard on the left and right-side in the figure do also have a buffer zone of 550 meter. The crashes inside these zones are showed in red, and these are not part of the count of the control group. The crashes in the control group are shown in blue.

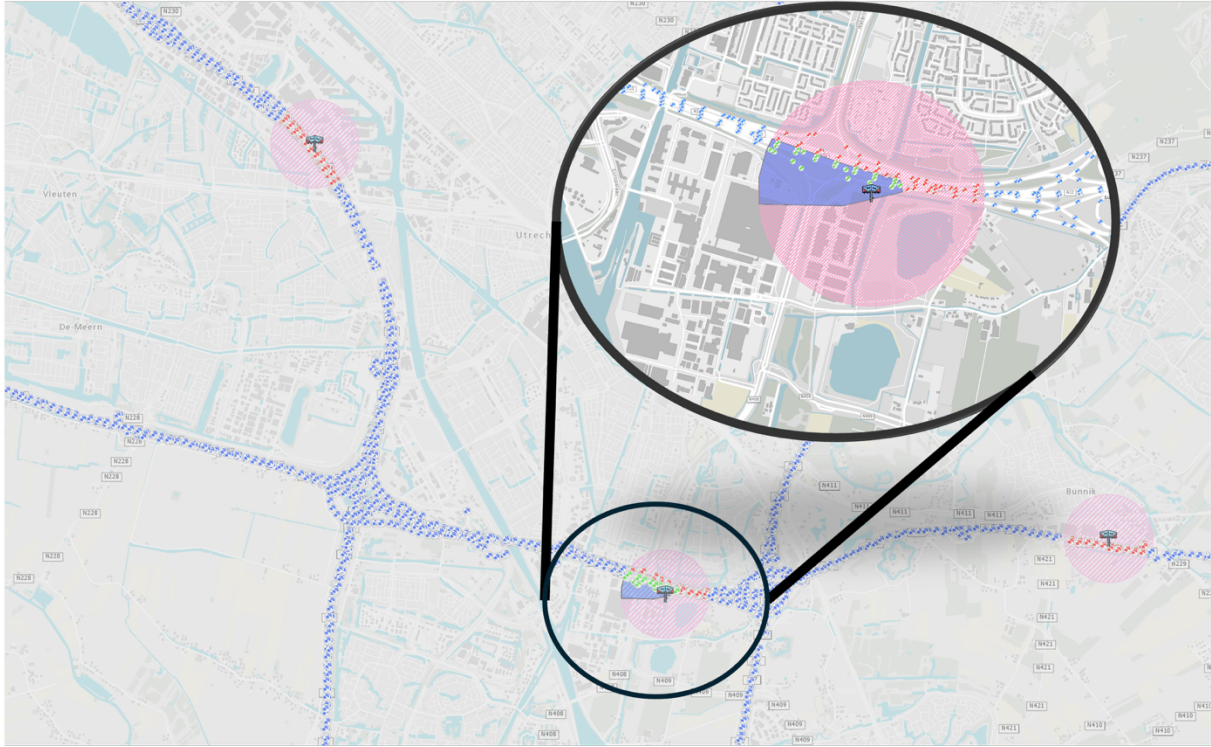


Figure 6: Buffer zones around every billboard in the dataset

2.3.2. Data analysis

In ArcGIS Pro, the treatment sites and control sites are displayed, as well as all crashes. It is therefore possible to count all crashes within the treatment sites per year and count all crashes in the control group, also broken down per year. After the crash count analysis in ArcGIS Pro has been done, the following data is collected for all 21 analyzed billboard locations i :

- (μ_{Bi}) : The number of crashes that happened in the influence zone of billboard X in the *before period* (Treatment site).
- (μ_{Ai}) : The number of crashes that happened in the influence zone of billboard X in the *after period* (Treatment site).
- (C_{Bi}) : The number of crashes that happened outside the buffer zone of every billboard in the *before period* (Control site).
- (C_{Ai}) : The number of crashes that happened outside the buffer zone of every billboard in the *after period* (Control site).

The data is exported into Microsoft Excel, where the before-and-after analysis will be conducted. The analysis structure is adopted from Yannis et al. (2013).

The estimated effect per billboard location i can be estimated, this is done via the following formula:

$$\text{Estimated effect } (\theta_i) = \frac{\mu_{Ai}/\mu_{Bi}}{C_{Ai}/C_{Bi}}$$

So, for one analyzed digital billboard location, the number of crashes that happened within the influence zone of that billboard location *after* placement/digitization are divided by the number of crashes in the same zone over the years *before* placement/digitization. This odds ratio is then divided by the odds ratio of the control group. This estimate has a statistical weight, which is dependent on the number of observed crashes. The higher the observed numbers in the analysis, the larger the statistical weight. It is calculated by:

$$w_i = \frac{1}{\frac{1}{\mu_{Ai}} + \frac{1}{\mu_{Bi}} + \frac{1}{C_{Ai}} + \frac{1}{C_{Bi}}}$$

Logically, the higher μ_{Ai} , μ_{Bi} , C_{Ai} and C_{Bi} are, the larger the statistical weight. This is the statistical weight of the estimated effect of one billboard location. To estimate the effect for all billboard locations, a *weighted mean effect* is used, this is calculated by:

$$WME = \exp\left(\frac{\sum_i w_i \ln(\theta_i)}{\sum_i w_i}\right)$$

After which a 95% confidence interval is calculated by:

$$\left[WME * \exp\left(\frac{z_{\frac{\alpha}{2}}}{\sqrt{\sum_i w_i}}\right); WME * \exp\left(\frac{z_{1-\frac{\alpha}{2}}}{\sqrt{\sum_i w_i}}\right) \right]$$

Where:

$$z_{\frac{\alpha}{2}} = -1,96$$

$$z_{1-\frac{\alpha}{2}} = 1,96$$

The global safety effect (expressed as a percentage), results from the weighted mean effect by:

$$(1 - WME) * 100$$

A result is statistically significant when the whole 95% confidence interval is on one side of the scale, either positive or negative. So, for example, when a safety effect of 15% is estimated by the model, with a 95% confidence interval ranging from [-10%; +40%], there is no significant effect. However, when the estimate is 15%, with a range of the confidence interval [+2%; +100%], there is a significant *positive* effect, although the exact size of the effect is quite uncertain, as indicated by the large confidence interval.

3. Literature review

This chapter dives into the recent literature on roadside advertising. All synthesized literature is from 2019 onwards. As subjects to analyze the literature, the current criteria in the Dutch assessment framework are used. The findings are consequently structured per criteria.

3.1. Barrier criteria

3.1.1. Lateral distance

The first criterion mentioned in the Dutch policy guidelines for assessment framework is the distance from the advertising object to the road, the so-called lateral distance. This is an important criterion, as the policy framework is used for assessing if an advertising object is permissible on a certain location.

The placement and distance between the road and the advertising object is studied by Costa et al. (2019). In their naturalistic driving study (N=15), they found that roadside advertisement that the clearance from the road is a significant predictor for fixation rate. The more clearance, thus the bigger the lateral distance, the lower amount of fixations by drivers occurred (Costa et al., 2019).

The elevation of roadside advertising is a subject studied by Crundall et al. (2006). This research is used as evidence-base in the Dutch assessment framework and still a leading study in this specific subject. Crundall et al. (2006) found that street-level advertisements (SLA) gain more fixations than raised-level advertisements (RLA). Recent studies of Berger Haladova et al. (2024), Cernekova et al. (2024), as well as Costa et al. (2019) confirm this finding. The elevation of an advertisement along the road is inversely related to the fixation rate and fixation duration of the studied drivers (Costa et al., 2019), thus lower elevated advertisements gained longer fixations.

Apart from lateral distance and elevation (vertical distance), Costa et al. (2019) also included the placement side of the advertisements along the road. They made a distinction between the driver's side (driver seat was on the left side, since this was a naturalistic driving study conducted in Italy) and the non-driver side. Advertisements signs that are placed on the driver's side of the road, receive significant more attention by drivers than signs on the non-drive side of the vehicle (Costa et al., 2019).

3.1.2. Moving images

The second criteria the Dutch assessment concerns the use of moving images (video) on digital billboards, as well as flashing, special effects and the frequency of changing images (Rijkswaterstaat, 2019). With regard to roadside advertising and road safety, these are one of the most studied subjects in (recent) literature.

About the use of video-based content on advertising objects along roads is the literature conclusive and consentient. This is more distracting than static content and it is recommended that the use of videos should be avoided (Wang et al., 2021; Brome et al., 2021; Felisberto & Casarin, 2024). Alqudah et al. (2025) found via a self-reported survey in Qatar, that people also find video and digital advertising object along the road more distracting than static content. Wang et al. (2021) conducted a simulator study using technology for eye-tracking and measuring brain activity. They concluded that the engagement of the participants is much higher for dynamic billboards than for static billboards. Especially during the interpretation phase, which comes right after the fixation phase, dynamic billboards required more 'working memory' of the brain (Wang et al., 2021), which ultimately leads to distraction.

Brome et al. (2021) compared all three forms of digital billboards in their study: animated, changeable (transitioning) and static (non-transitioning) billboards. They showed that animated billboards, i.e.

video-based content, caused significant more lane deviation than dynamic, static and no present billboard. The reaction time to traffic lights increased significant with respect to the other billboard categories. Also, the percentage of fixations on billboards and duration of fixation are significant higher for animated billboards (Brome et al., 2021). When measuring the number of gazes, transitioning billboards attracted the highest amount of gazes per billboard. A transitioning billboard received 2.41 gazes on average (s.d. = 0.79) while animated billboard received significantly lower with 2.16 (s.d. = 0.89). This is most likely due to the transitioning nature of this type of billboard. People tend to look more often, in order to see something new, a new transition. Overall, the video-based billboard attracted more and longer fixations, while transitioning billboards attract more gazes. Brome et al. (2021) concludes with that there should be warned for dynamic and especially animated billboards and opt for static billboards for the safety of road users.

In a comprehensive literature review in 2019, Oviedo-Trespalcios et al. (2019) concluded that changeable advertising signs have a detrimental impact on driver's attention. Also, the use of flashing effects on digital billboards gains attraction (Oviedo-Trespalcios et al., 2019). Felisberto & Casarin (2024) as well as Jaskowski et al. (2025) also mention the changes in luminance. These changes cause a flashing effect, involuntary attract more attention from drivers and also effect the (dis)comfort of drivers (Jaskowski et al., 2025). Besides, Felisberto and Casarin (2024) mention that no visuals (special effects) should be used for transitioning one (advertisement) image into another. They refer in their literature review to a conference paper of Roberts (2013) where evidence-based guidelines are presented for Australia. Using no special effects for transitioning is one of the proposed guidelines in this paper (Roberts, 2013).

3.1.3. Dwell time

The change in lighting occurs when changing from one image into another, this transitioning is common on digital billboards. Therefore, an often-covered subject in both scientific research and policy guidelines is the dwell time. Dwell time is the time between transitions of images. For example, in the Netherlands this is one transitioning per 6 seconds (dwell time = 6 s, which means 10 images per minute), with no further driving aggravating circumstances on the corresponding road segment (Rijkswaterstaat, 2019).

Oviedo-Trespalcios et al. (2019) states in his literature review that changeable signs make up for greater distraction than static (single-image) signs. He concludes his review with the recommendation that drivers should be able to see "only one image per interaction with a roadside advertising sign." (Oviedo-Trespalcios et al., 2019, p. 93). He suggests for a dwell time larger than 10 seconds, which is mentioned as a conservative approach. However, at the same time Oviedo-Trespalcios et al. (2019) concludes that the knowledge for the right dwell time is still not enough.

Hinton et al. (2022) and Felisberto and Casarin (2024) state that shorter dwell time cause more glances that longer dwell times. They refer in their literature overviews to Mollu et al. (2018) (Hinton et al., 2022; Felisberto & Casarin, 2024). Mollu et al. (2018) conducted a Belgian simulator study to the effect of digital billboards near pedestrian crossings. The study used three different dwell times to vary with: 3, 6 and 15 seconds. It was found that the average number of glances increased significantly when using shorter dwell times, wherefore the conclusion was that longer dwell times are better, and shorter dwell times should be avoided (Mollu et al., 2018). The study of Mollu et al. (2018) is mentioned in the Dutch assessment framework and will be briefly discussed in the discussion section of this chapter.

Another study to dwell times is conducted by Meuleners et al. in 2020. This was an Australian study, also carried out by using a driving simulator. Their conclusion was the same as Mollu et al. (2018): longer dwell times generate significantly more glances and therefore had less impact than shorter dwell times. However, a difference between the studies, was the studied dwell times, Mollu et al. (2018) used 3, 6, and 15 seconds, while Meuleners et al. (2020) used 20, 40 and 60 seconds, which can be seen as a significant

difference. Only when a simple message is displayed in combination with a long dwell time (60s), no negative effects were found (Meuleners et al., 2020).

In an evidence-based guidelines proposal of Roberts (2013), a formula for determining an appropriate dwell time is presented. Felisberto and Casarin (2024) mentioned this dwell time formula in their literature review:

$$DT > \frac{VD}{SE * 0.28}$$

Where:

DT = Dwell time in seconds

VD = Visibility distance in meters

SE = Speed environment (speed limit) in kilometers per hour

The formula is based on the basic principle that distance divided by speed results in time. As the guiding principle is that road users must only see a maximum of one image change, the dwell time in this formula must be *greater than* the time is needed to cover a certain distance with a certain speed. In his conference paper, Roberts (2013) did not specify the fixed parameter of 0.28. However, after corresponding with Dr. Paul Roberts, it was confirmed that this parameter corrects for the use of both km/h and meters and seconds in the formula. As $1/3.6 \approx 0.28$ (Roberts, personal communication, December 9, 2025). It was unclear to Roberts why the formula was not written as follows at the time of construction:

$$DT > \frac{VD * 3.6}{SE}$$

3.1.4. Light emission and luminance

Both static and digital forms of roadside advertising make use of lighting sources. Either spotlights are used to light up the object, or, in case of digital billboards, the screen itself emits light. In a simulator study to light emission, luminance and different colors of lighting, He et al. (2021) found that the bigger the light panel, the bigger the discomfort glare is. He concluded that the size of the lighting source matters. Another factor that plays a significant role is the maximum luminance, how bright the brightest part of the lighting source is (Jaskowski et al., 2025). Although the average luminance of the source also has a significant effect, the maximum luminance contributes the most to driver discomfort. For example, a quite dark, Halloween themed billboard, where the eyes of a pumpkin are brightly lit up. The average luminance of a billboard like this may not be very high, but the maximum luminance of the eyes plays a bigger part in causing discomfort glare. In the same study by Jaskowski et al. (2025), it was found that contrast of a lighted screen with regard to its background is a predictor for driver discomfort. Contrast is a crucial factor, as Jaskowski et al. also found that the change in environment luminance is a factor for driver distraction. In and out of tunnels for example, the change in environmental luminance changes, and together with a light emitting billboard, this is causing veiling luminance, ultimately leading to driver distraction (Jaskowski et al., 2025). The lighting conditions during nighttime were investigated by He et al. (2021). In this study, it was found that for low environmental luminance, the participants of this simulator study had more missing dots for safety risks. This indicates an increase in safety risk. Sheykhfarid et al. (2024) also found that during nighttime, drivers are more likely to be distracted by digital billboards.

As for policy recommendations, Oviedo-Trespalacios et al. (2019) adapts a guideline from Roberts (2013), stating that luminance of digital billboards should not exceed the luminance of static signs, especially in lowlight conditions. Another recommendation by Oviedo-Trespalacios is that the luminance of advertising signs should be within a range of 10 to 40 times the luminance of other light emitting objects on the road, headlights are mentioned as an example. Where luminance is often already taken into account in policy guidelines, Jaskowski et al. (2025) recommends that every advertisement sign is assessed on a luminance contrast factor, in order to prevent a different contrasts for advertisement signs, while using the same

luminance values. After all, the contrast differs based on the location and the background of the advertisement sign.

3.2. Consideration criteria

3.2.1. Driving task aggravating locations

While the above-mentioned three criteria are so-called barriers criteria in the Dutch assessment framework, this criterion is the first of the consideration criteria (Rijkswaterstaat, 2019). However, this criterion is quite prevalent in the framework as well. The influence of roadside advertising in driving task aggravating circumstances and locations is explored in a naturalistic driving study by Sheykhfard et al. (2024). The study was conducted in Iran and found that at intersections, which can be marked as a driving task aggravating location, the probability for driver distraction was high (Sheykhfard et al., 2024). The distraction nearby intersections is found to be twice as high as for other road types. It is recommended to prevent the placement of roadside advertising along nearby intersections (Sheykhfard et al., 2024).

A Croatian study of Vrkljan et al. (2022) emphasized increased danger when advertisements are placed in high-speed traffic environments. Sorum and Pal (2022) mention that nearby intersections and high-demanding corners and bends, roadside advertisements should be prohibited for placement. Hinton et al. (2022) and Oviedo-Trespalcios et al. (2019) both also state that complex and rapidly changing traffic locations are more safety-critical. Wherefore it is recommended that roadside advertising should not be placed in these locations (Oviedo-Trespalcios et al., 2019).

3.2.2. Resembling to traffic related information

Traffic signs and traffic information panels contain relevant information for safely performing the driving task and thus are important for informing road users (Bucsuházy et al., 2025). In the Netherlands, these traffic signs and information panels are often blue with white text, or yellow with black text (Rijkswaterstaat, 2019). Although in literature, specific research on advertisements that look closely like traffic information is not conducted, there are findings on how traffic information signs and advertisements signs interact. In an eye-tracking study by Bucsuházy et al. (2025), there was concluded that drivers often have difficulties with differentiating traffic signs (relevant traffic information) and roadside advertisements (irrelevant traffic information). The overload of information on roadside advertisements can cause drivers to no longer sufficiently detect traffic information signs, which potentially results in a safety risk (Bucsuházy et al., 2025).

In a questionnaire study in Qatar, Alqudah et al. (2025) found that traffic signs and static and digital billboards do compete for attention. The gaze at static and digital billboards and the gaze at traffic signs are significantly negatively correlated with each other. However, it should be noted, this is a self-reported questionnaire study, where memory and social desirability bias are limitations (Oviedo-Trespalcios et al., 2019).

3.2.3. Expectancy

When looking for information, drivers make use of endogenous selection (Walker & Trick, 2019). People look for information they expect to be present on a sign and expect to interpret this information quickly. To minimize the glance duration, the expectancy of displayed information on both traffic and advertisement signs should preferably be high. This is emphasized as interpretation takes time and resources which compete with attention resources for performing the driving task (Harasimczuk et al., 2021). Longer slogans for example take interpretation time and are found to have an effect on reaction time (Harasimczuk et al., 2021). In another study, by AlKheder et al. (2024), it was found that the bigger size the advertising sign is, the bigger the impact on driver distraction is. This effect was statistically significant and resulted from an eye-tracking study done in Kuwait. The influence of larger panels and screens is also

emphasized by Mustapić et al. (2021). In his study, Mustapić et al. (2021) researched the influence of billboards on younger drivers. He found that besides the impact of larger screens, also the presence of well-known brands has an effect on younger drivers. These brands attract more attention than less-known brands (Mustapić et al., 2021). Costa et al. (2019) investigated the text characteristics of roadside advertising, after which he concluded that large font size of text and the amount of textual content are a good predictor for fixation duration.

The amount of billboard content characteristics also plays a significant role in driver distraction. Harasimczuk et al. (2021) also showed that longer slogans reduce driving performance, and he recommends that advertisements should not contain seven words or more. Marciano (2020) similarly concluded that billboards with richer graphics and minimal text are less likely to impair performance than those requiring more reading. The amount of information drivers must process appears to be central: Meuleners et al. (2020) found that simple billboard content with a dwell time of 60 seconds resulted in the least negative impact compared to more difficult content shorter dwell times. This indicates that dwell time and amount of information both impact the driver fixation with billboards. In line with this, Harasimczuk et al. (2021) argued that the danger does not stem from merely glancing at a billboard, but from having to process and respond to its information. This additional cognitive load reduces attentional processing efficiency, ultimately diminishing driving performance.

3.2.4. Emotionally loaded content

Mustapić et al. (2021), in a study to younger drivers, found that sexual content also draws the attention of younger drivers significantly. Sorum and Pal (2022) mention that the influence of this content does not apply exclusively to younger drivers. In their nation-wide survey in Poland as well as in an attention response test as well as a driving simulator study, sexual content was attracting attention. In the self-reported survey, drivers found sexual advertisement content both distracting and dangerous. On the attention response test, participants had a higher response time on cognitive tasks when sexual content was present. Third, driving performance decreased during the driving simulator study in a presence of sexual-loaded content on roadside advertisement (Sorum & Pal, 2022). Oviedo-Trespalacios et al. (2019) also mentions that sexual images on roadside advertising increases gaze direction.

While sexual loaded content being the most represented in the literature, other forms of emotional content exist. Taboo words for example are found to be distracting as well (Oviedo-Trespalacios et al., 2019). Walker and Trick (2019) found effects of both positive and negative loaded content; after being exposed to roadside advertisements with such content, the lateral control of drivers decreased. Walker and Trick (2019) mention that emotionally loaded content stimulates the exogenous selection of drivers, rather than expecting information on an advertisement sign, drivers are diverted to this content because of the load of the content. It unwillingly overrides the focus on the road (Walker & Trick, 2019).

3.2.5. Blocking of the road view

The perception of a driver is optimal when everything on the road, relevant to the driving task, is visible (Harasimczuk et al., 2021). Therefore, it is important that drivers should have a clear view of the road. Rijkswaterstaat (2019) also mentions this in their criterion regarding misleading. They state that (advertising) objects should not mislead road users in terms of blocking the vision or perception of the road view. Costa et al. (2019) therefore argues that advertisement placed on curves are considered problematic. Not only because of driving aggravating nature of curves, as discussed in paragraph 3.2.1, but also because billboards can block the view of the road (Costa et al., 2019). Yang et al. (2024) conducted a driving simulator study in China using eye-tracking technology to research the influence of roadside advertisements on traffic signs. One of the main findings was that roadside advertisements should be placed behind traffic signs rather than nearby of even in front of traffic signs (Yang et al., 2024).

3.2.6. Blue light

Only one study explicitly mentioning blue light was found in while reviewing the literature. In this study to lighting conditions and light emission of digital billboards during nighttime, He et al. (2021) used different colors on digital LED billboards to vary with. He et al. (2021) found that two colors differ from the rest of the spectrum, when it comes to causing driving errors. Billboards using blue and cyan-blue light, which can both be seen as part of the blue light category, increase the reaction time of drivers and also increase the number of missing dots (He et al., 2021). Missing dots are safety risks that are missed by participants in this driving simulator study. Besides blue and cyan-blue, other colors used on the LED billboard did not decrease the reaction time. The amount of missing dots however, still increased. The simulator study made use of 24 participants, of which 12 are male and 12 are female. An interesting finding is that female participants scored better on reaction time (lower reaction time) as well as on missing dots. He et al. (2021) concludes with a recommendation to strictly limit the use of blue and cyan-blue light on billboards during nighttime.

3.2.7. Spatial quality and landscape integration

Landscape and spatial quality are an important factor in road planning. The aesthetics of a road are seen as important for stress regulation of road users and scenic routes are managed in national programmes (Anciaes, 2023). Where monotonous views contribute to driver fatigue, roadside nature and aesthetics can reduce both stress and risky driving behavior (Anciaes, 2023). Although it is known that the quality of roadside effects the satisfaction of drivers, a lot of emphasize in literature is placed on road safety issues, while spatial quality and landscape enjoy less scientific attention. Drivers prefer ‘green and blue’ nature (water and grasslands) over man-made nature, like (D)-OOH advertising (Anciaes, 2023).

3.3. Discussion

Most of the criteria that are currently stated in the Dutch assessment framework are covered in recent literature. 24 scientific articles published in 2019 or later were analyzed, and their findings were structured per existing criteria. Three consideration criteria are not or not found to be covered in (recent) literature: sequencing of messages, moving object (non-advertisements) and the viewing angle.

The literature is quite conclusive and consentient regarding moving images. Digital billboards should not contain any form of video-based content. Rijkswaterstaat (2019) already has this prohibition included in their framework, but it could be strengthened with the mentioned literature in this review. Roughly the same applies to the use of blue light. Currently it is stated by Rijkswaterstaat (2019) that one should be reticent with the use of blue light, especially at night. However, two grey sources are mentioned about the working of blue light, and this analogy is used to argue for this criterion. The study of He et al. (2021) concluded that the use of blue and cyan-blue light should be strictly limited, so this conclusion could be directly implemented in the Dutch assessment framework. In the overview table below, all recommendations from literature and policy implications are displayed.

Table 3: Literature findings and policy implications

Assessment criterion	Insights by literature review	Recommendations for policy guidelines	Implications for policy guidelines
Lateral distance and elevation	Greater lateral distance reduces driver distraction (Costa et al., 2019). Regarding elevated signs: street-level signs attract more fixations (Costa et al., 2019; Cernekova et al., 2024). Costa et al. (2019) also found that placement on driver’s side increases attention.	Increase offset distance; avoid driver-side placement; prefer elevated placement.	Hard to provide and recommend exact distances and meters of elevation for placement guidance. Guidelines against driver-side placement seems hardly possible, as (Dutch)

			highways are almost everywhere two-directional.
Moving images	Animated content and video advertising increases fixation duration, lane deviation, and reaction time (Wang et al., 2024; Brome et al., 2024). In addition, flashing and luminance changes involuntarily attract attention (Jaskowski et al., 2025).	Prohibit moving and flashing content and limit transitioning content.	For details on transitioning content, it is harder to draw an evidence-based line for policy guidance; prohibition of use of video and animated content is clear.
Dwell time	Short transition intervals trigger repeated glances, and longer exposure reduces visual demand (Hinton et al., 2022; Felisberto & Casarin, 2024). Widely varying dwell times are studied, with same finding of longer is better (Mollu et al., 2018; Meuleners et al., 2020). However, optimal duration of dwell time is still debated (Oviedo-Trespalacios et al., 2019).	A guiding principle is to display only one image per driver. Apply longer dwell times, (preferably >10 s) and avoid short dwell times (<6 s).	As optimal dwell times are not identified, there is still room for discussion and different interpretation of appropriate dwell time. For example, a dwell time formula is constructed by Roberts (2013), but only slowly adopted by policymakers.
Light emission and luminance	Displays with higher luminance, as well as large, illuminated surfaces, and high contrast with natural background increase glare and distraction, especially in low-light conditions (He et al., 2021; Jaskowski et al., 2025).	Limit luminance levels, assess environmental contrast level and apply strict night-time thresholds.	Studies are consentient and clear on needed assessments and guidelines implications.
Driving task aggravating locations	Intersections, curves, and complex traffic environments increase safety risk when ads are present (Sorum & Pal, 2022; Sheykhfarid et al., 2024).	Avoid placement in cognitively demanding or high-speed road sections.	The studied literature is conclusive, but as these are intuitive findings, it is difficult to study and assess when a curve or intersection is cognitively too demanding.
Resemblance to traffic related information	Drivers can potentially confuse advertisements with official signage, as they both compete for driver attention, ultimately reducing attention toward traffic-relevant messages (Bucsuházy et al., 2025).	Placement on roadside advertising close to traffic signs should be prevented.	No specific research done on this topic, however, for policy guidelines, the recommendations are quite intuitive.
Expectancy	Long texts (Harasimczuk et al., 2021), brand recognition (Mustapić et al., 2021), size of the advertising sign (Mustapić et al., 2021) and information density (Marciano, 2020; Meuleners et al., 2020) increase fixation duration and interpretation time.	Use short slogans, minimal text (preferably ≤ 7 words), reduced content density and avoid oversized boards.	Details are often not specified, apart from number of words. Oversized boards and content density in general are for example not specified.
Emotionally loaded content	Sexual or emotionally loaded advertising content generates involuntary attention shifts and reduce performance (Walker & Trick, 2019; Sorum & Pal, 2022).	Prohibit explicit or emotionally provocative messaging.	Clear finding, although the line for what is considered (too) sexual or emotionally loaded is open for interpretation.
Blocking view of the road	Advertisements may obstruct the line of sight and/or interfere with visual perception of upcoming roadway (Costa et al., 2019; Yang et al., 2024).	Ensure unobstructed sightlines by preventing placement on curves and curved roads. Another recommendation is to always position roadside advertising behind traffic-relevant signage, rather than in front.	Minimal spacing between traffic relevant signs is not provided by studied literature. Furthermore, the same implications apply as for driving task aggravating locations. Judgement on demanding curves remains difficult.

Blue light	Blue and cyan illumination by roadside advertising increases reaction delay and causes more missed hazards on the road (He et al., 2021).	Limit blue and blue-cyan lighting on digital screens, especially at night.	Clear finding, although no hard limit is provided, the potential problematic colors are made specific.
Spatial quality and landscape integration	Scenic quality reduces stress and supports safer driving, while visual clutter contributes negatively to perceived scenic quality (Anciaes, 2023).	Maintain landscape visibility and quality by limiting clutter along scenic roads.	This topic received little scientific attention. There lies a lot of room for interpretation and discussion on this aspect.

3.3.1. Dwell time

Dwell time received quite a lot of attention in (recent) literature. Although it is hard to draw hard conclusions from existing evidence to construct concrete dwell time guidelines, it is agreed upon that the transition has a significant influence on the fixation of drivers. It is also a barrier criterion in the Dutch assessment framework. Therefore, dwell time receives some extra discussion in this literature review.

In the current Dutch framework, Rijkswaterstaat (2019) used Mollu et al. (2018) as scientific foundation for maintaining 6 seconds as lower limit for dwell time, as this number was introduced in the first version of the framework in 2011 (Rijkswaterstaat, 2019). In 2011, the 6 seconds was adopted from a dwell time used by the New York Department of Transportation (NYDOT, 2008b; Rijkswaterstaat, 2019). However, initially, the NYDOT suggested 62 seconds (NYDOT, 2008a), a number that was based on evidence and human factors assumptions, according to Wachtel (2009). These initial suggested criteria were introduced on April 11, 2008. The revised suggested criteria, in which the dwell time was reduced from 62 to 6, were presented only 3 months later. Reasoning behind this decrease in dwell time was that this revision should be 'less restrictive'. It raises the question why the 6 second dwell time was adopted by Rijkswaterstaat, as the initial dwell time of 62 seconds was based on calculations that by using this number, only one change could be seen by drivers within the readability distance (NYDOT, 2008a; Wachtel, 2009), while the 6 second dwell time was solely based on being 'less restrictive' (Wachtel, 2009).

Rijkswaterstaat (2019) also mentions in the Dutch framework that dwell time should be based on the principle that drivers should be exposed to only one change in advertisement, within the distance that drivers are able to *read* such advertisements (Oviedo-Trespalacios et al, 2019). This readability distance is hard to assess and may differ for almost every location. Rijkswaterstaat gives no number, only the above-mentioned definition of readability distance. For a dwell time of 10 seconds, Rijkswaterstaat (2019) argues that drivers would be exposed to only one change within the distance that drivers are able to see an advertisement; the so-called visibility distance. The mentioned formula by Roberts (2013), also uses visibility distance as critical parameter. However, if for Dutch highways this formula would be filled in, the visibility distance and dwell time are hardly in balance.

$$DT > \frac{VD}{SE * 0.28}$$

Where:

DT = Dwell time in seconds

VD = Visibility distance in meters

SE = Speed environment (limit) in kilometers per hour

For a speed limit of 100 km/h, which is common during daylight in The Netherlands (Rijkswaterstaat, 2025), and a dwell time of 10 seconds, this would result in a *visibility distance* of maximum 280 meters, which is not a lot. For example, 550 meters is set as influence zone buffer in the before-and-after analysis of this thesis (see paragraph 2.3.1.1); significantly more than 280 meters. Therefore 10 second dwell time

does not seem very plausible to state that this would expose drivers to only one change within the visibility distance. Currently, in the Dutch assessment framework, it is stated that this dwell time and corresponding visibility distance are based upon expert-input. It would be insightful to include this calculation or expert-rationale into the assessment framework.

According to Roberts (personal communication, December 9, 2025), the reason why his dwell time formula is not widely adopted by policymakers are complex and political. As policymakers are keen to use fixed dwell time(s) for constructing guidelines, the implementation of a changeable dwell time, based on situational factors as visibility distance, is only slowly adopted.

4. Best practices in other countries

4.1. Country selection

4.1.1. CARE database

As described in paragraph 2.2.1.1, the CARE, ETSC and OECD databases are used to make the first selection of countries to be reviewed. In the most recent CARE database, the number of fatalities of 2023 are reported. These are reported per million inhabitants. Norway had the lowest annual road deaths in 2023, reporting 20 fatalities per million inhabitants. The Netherlands had 34, while the EU average was 46 fatalities per million inhabitants (European Commission, 2025). The countries that performed better and/or similar are noted, after which the ETSC and OECD data are used to check and refine the list of countries.

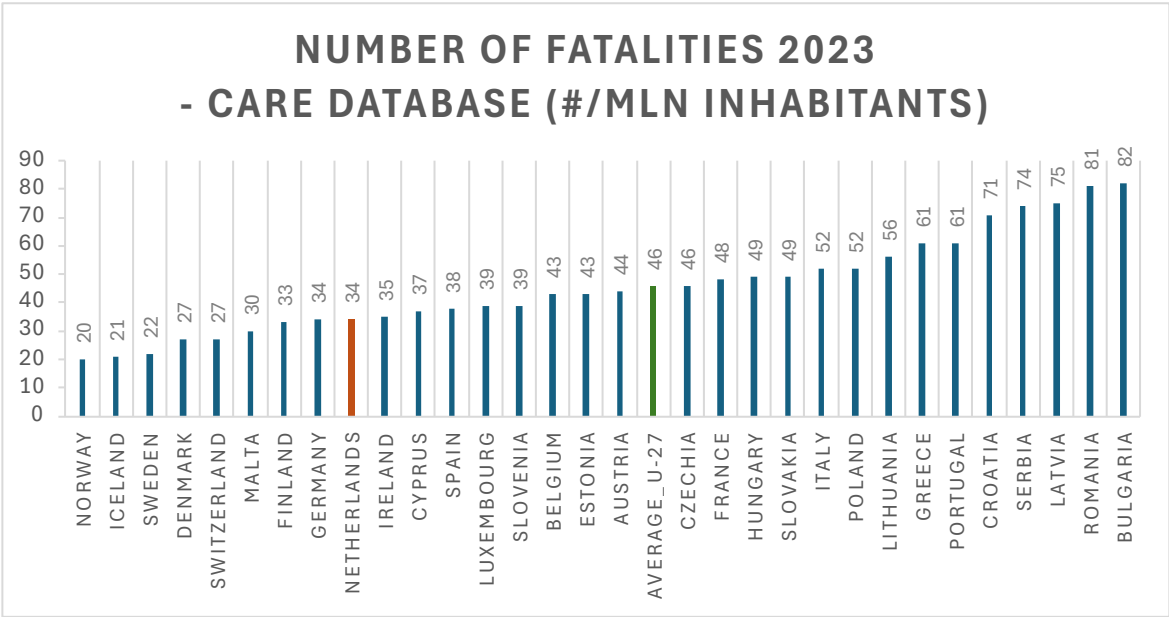


Figure 7: Fatalities per million inhabitants (European Commission, 2025)

4.1.2. ETSC database

In the database of the European Transport Safety Council (ETSC), there are both figures included on number of fatalities per million inhabitants as well as per billion vehicle-kilometers travelled. Both are used to assess relevant countries. The database of the ETSC uses data from 2024, and small differences are found compared to the CARE database. Norway still outperformed the rest of the countries, both per inhabitants as per vehicle-kilometers travelled. Important note is that in this database, numbers of the United Kingdom are included, which also has a relatively low number of annual fatalities. Another finding is that Luxembourg had a slightly higher number of fatalities per million inhabitants compared to the Netherlands, while in the ETSC database this number of Luxembourg was lower. This could be due to more recent numbers (2023 vs 2024) and Luxembourg making quite rapid progress on lowering their number of road fatalities per million inhabitants (European Commission, 2025; ETSC, 2025).

For the vehicle-kilometers travelled, no big differences are found, the list of better and similar performing countries remained roughly the same. One thing did stand out, when comparing France and the Netherlands on fatalities per million inhabitants, France had worse numbers. However, France scored almost similar to the Netherlands when using vehicle-kilometers as metric. The same finding applies for Slovakia (ETSC, 2025).

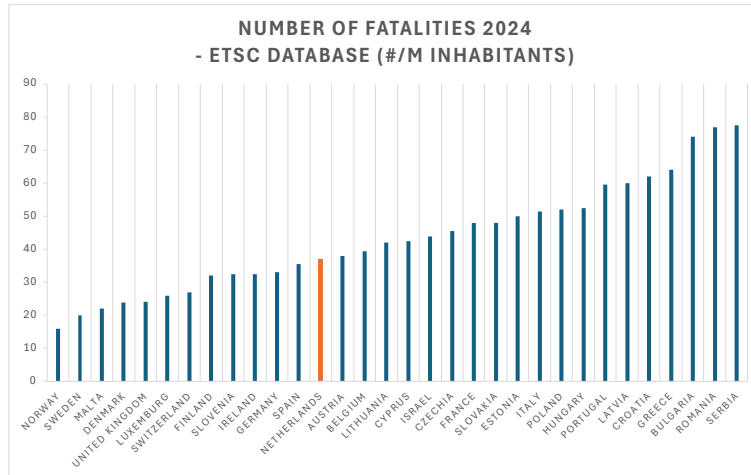


Figure 8: Fatalities per million inhabitants (ETSC, 2025)

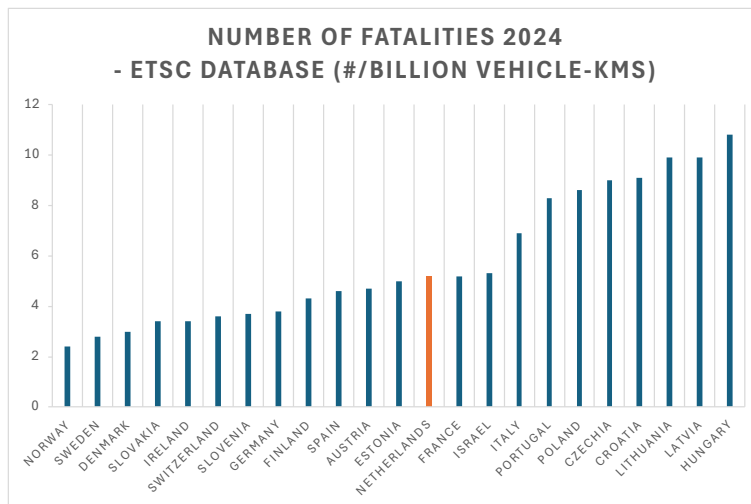


Figure 9: Fatalities per billion vehicle-kilometers (ETSC, 2025)

4.1.3. OECD database

The Organization for Economic Co-operation and Development (OECD) also has a database on risk figures. It is presented in a report from the International Transport Forum (ITF, 2024). This report presents the results on fatalities per hundred thousand (instead of one million) inhabitants and per billion vehicle-kilometers travelled, just as the ETSC database does. In this database, other countries than only European ones are included; Japan for example had a relatively low number of fatalities per hundred thousand inhabitants. The worst performing countries per hundred thousand inhabitants were non-European, being Costa Rica, Colombia and the United States of America (ITF, 2024). When looking at the fatalities per billion vehicle-kilometers travelled, Australia scores slightly better than the Netherlands.

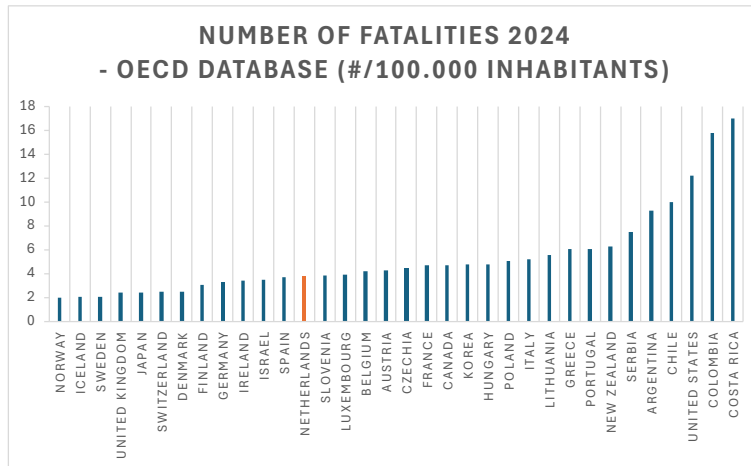


Figure 10: Fatalities per 100.000 inhabitants (ITF, 2024)

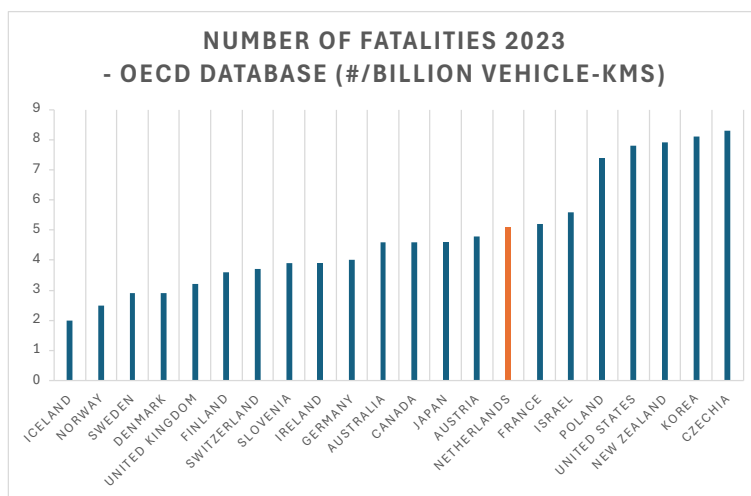


Figure 11: Fatalities per billion vehicle-kilometers (ITF, 2024)

After reviewing all three databases on road fatality risk figures, the following 24 countries are selected:

Australia; Austria; Belgium; Canada; Cyprus; Denmark; Estonia; Finland; France; Germany; Iceland; Ireland; Israel; Japan; Luxembourg; Malta; New Zealand¹; Norway; Slovakia; Slovenia; Spain; Sweden; Switzerland and United Kingdom.

4.1.4. WEF database

A database from 2019 of the World Economic Forum (WEF) on road quality is used to determine road quality of the countries initial selected on fatality risk figures. The quality of the road infrastructure is scored by the WEF on a scale of 1 to 7, where higher is better. From the selected countries, the Netherlands scores the second-highest on this number (6.4), with only Switzerland and Japan scoring 6 or higher (WEF, 2019). As lower limit, 4.5 is chosen as score. This is chosen to filter out countries which are significantly differing from the Netherlands. Finding directly comparable countries on this statistic is difficult, as the Netherlands scores very high, but using 4.5 as lower limit, the worst performing countries are identified. Countries noting a lower score than this, are excluded from the country selection. This

¹ Although New Zealand did not perform that well or similar to the Netherlands, it is decided to include this country based on the extensive, recent and readily available guidelines and legislation of New Zealand.

concerns five countries, which are Ireland (4.48), Belgium (4.39), Iceland (4.14), Malta (3.24) and Slovakia (3.96) (WEF, 2019).

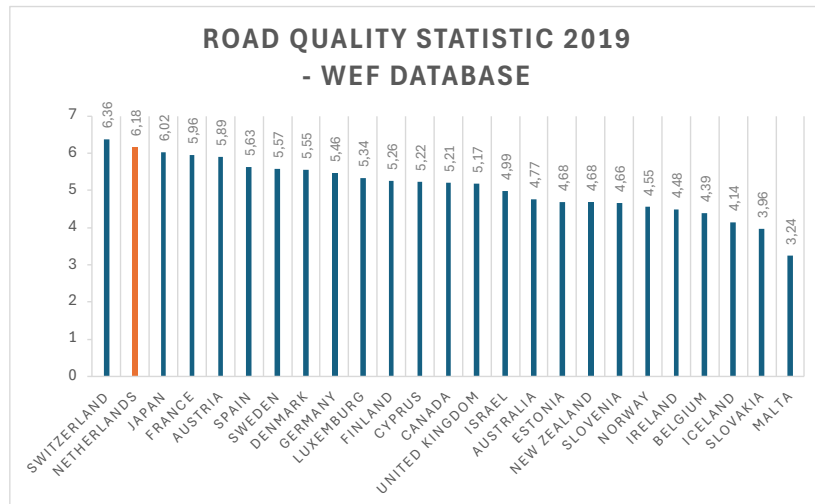


Figure 12: Road quality statistic (WEF, 2019)

4.1.5. Cultural similarities

Five countries are excluded due to low road quality statistic, whereafter 19 countries remain. As described in paragraph 2.2.1.1, culture is also an important indicator for assessing relevant countries to compare. Japan scores for example similar to the Netherlands on road quality and on annual fatalities, but the cultural differences compared to the Netherlands are considered to be large. The same applies for Israel, Canada and Australia. These three are non-European Union (EU) countries, although this is not the hard line for inclusion or exclusion. Norway for example, is also not a member of the EU, but found to be similar enough, the same applies for the United Kingdom and Switzerland. New Zealand is also non-EU countries but is still included for further comparison. Vice versa, there are also EU countries that are, although being part of the EU, found to differ from the Netherlands too much. This concerns Cyprus, Estonia and Spain.

4.1.6. Available best practices

Another important limitation is if the provisional selected countries have available information on guidelines and/or legislation on roadside advertising. The search procedure as described in paragraph 2.2.1.2 is followed. The included countries in the ChatGPT 5 search process are:

Austria; Denmark; Finland; France; Germany; Luxembourg; New Zealand; Norway; Slovenia; Sweden; Switzerland; United Kingdom

After the search process was done, the following countries were included in the final analysis:
Denmark; Finland; France; New Zealand; Norway; Switzerland; United Kingdom

Below is per searched country a brief explanation on the search results. This is done to give insight in the results the used AI tool gives, as an AI tool as ChatGPT 5 operates as a black box, where results can differ per user, even when the exact same input is used (Peres et al., 2023).

4.1.6.1. Included countries

For Denmark, ChatGPT 5 returned a document of *Vejdirektoratet*, which is the Danish counterpart of Rijkswaterstaat (Retsinformation, 2025). The document contains advisory information for municipalities for assessing traffic impact of advertising signs. It is similar to the Dutch assessment framework but more concise and kept simple for advisory sake (Vejdirektoratet, 2015). It is 11 pages, and no used literature is

mentioned for example. At the beginning of the document, it is stated that this document is based on Norwegian guidance. The document is drawn up in January 2015. After screening the *Vejdirektoratet* website on other information sources, another helping guide on illuminated advertising from December 2018, was found. Both documents were in Danish and therefore were translated to English (Vejdirektoratet, 2018).

Another source regarding Denmark that was provided as a result of ChatGPT 5's search process was *Retsinformation*. *Retsinformation* is an official Danish online information portal, where legal information is stored and openly accessible (Retsinformation, 2025). Here, section 21 of the Danish Nature Protection Act is found. This section contains official information on advertising in the open countryside and is ought to be especially helpful for information on landscape integration and spatial quality (Retsinformation, 2021). This document was in Danish and needed to be translated.

For Norway, ChatGPT 5 directed to the permit application page. Attentively enough, the Norwegian government does provide on this page also directly the official information on roadside advertising where these permits applications are judged upon (Statens vegvesen, 2021). This application webpage was in English already, but the assessment information that can be downloaded from this webpage is in Norwegian. So, this document needed translation to English. It is a large document, containing 88 pages. It is a document from *Statens vegvesen*, which is the Norwegian Public Roads Administration. This is the road agency of Norway and thus exactly like Rijkswaterstaat in the Netherlands (Regjeringen, 2025).

Two documents were retrieved for Switzerland. One working guide and one small, concise information sheet. The working guide count 27 pages and is in build up again comparable to the Danish and Norwegian ones. It was found on the webpage of the canton of Bern, Switzerland's capital (Kanton Bern, 2025). This working guide was released in May 2022, and the language was in German, so translation was made accordingly. The information sheet dates from October 2016 and was released by the SVI Swiss Association of Traffic Engineers and Traffic Experts (SVI, 2016). This information sheet provides a summary of research findings on the effects of advertising in public spaces. It is intended to support decision-making for permits of roadside advertising (SVI, 2016).

The official information from the United Kingdom was more straightforward to find, ChatGPT 5 directly links to a governmental webpage named 'Guidance – Advertisements' (Gov.uk, 2019). The information was last revised in 2019 and was logically already written in English.

A governmental website for Finland was also directly found by ChatGPT 5. The website was from the *ELY*, the Finnish Centre of Economic Development, Transport and the Environment. Although there is an English version of the website, this concerns a simplified version. Also, ChatGPT 5 directly linked to the right page (in Finnish) regarding advertisement placements along roads (Traficom, 2019). The website was translated via Google Translate, whereafter it was possible to download a pdf with the Finnish Guidelines on roadside advertising. The document comes from *Traficom*, the Finnish Transport and Communication Agency, which again, is the Finnish equivalent of Rijkswaterstaat. This document had 8 pages and was also translated.

The French information was, just like United Kingdom, found by ChatGPT 5 on the government website of France (Legifrance, 2014). Here, a document from the Ministry of Ecology, Sustainable Development and Energy was found on guidance on public advertising, including information on roadside advertising. The translation of the document was done by Google Translate.

New Zealand has very recent documentation on digital roadside advertising (NZTA, 2025). This guidance (draft) document is from late September 2025 and was already encountered during the literature review of this thesis. The New Zealand guidance document cites, among others, Molino et al. (2009) and Vlakveld and Helman (2018), this way the document was found before the ChatGPT 5 search process was

conducted. In addition, this document was marked as interesting and send to me by my supervisor, Oviedo-Trespalacios. ChatGPT 5 did not directly find this document but did find a manual on roadside advertising in general, without specific focus on digital billboards, likewise from the NZTA (2011).

4.1.6.2. Excluded countries

For Austria, there is known to be official information available, and ChatGPT 5 did link to the correct webpage. However, this information from the Austrian road agency is behind a paywall of the Austrian government (WKO, 2024). Therefore, it was decided to exclude Austria from further analysis.

For Germany, an extensive guidance document was found on advertising at rest areas (Helmer et al., 2024). Although there are similarities to other guidance frameworks regarding the coverage of placement and sign content specification, it was still decided to leave out Germany for further analysis. The spatial planning of rest areas is outside the scope of this thesis and therefore the German guidelines are not included.

ChatGPT 5 did find the official information for Slovenia on their official database for public information PISRS (2022). Here, the roads act is stored and publicly available. Section 89 of the roads act briefly covers advertising along national roads. The website was in Slovenian and was therefore translated by Google Translate. However, as this information is only 500 words in total, it was judged as too little to include into the analysis.

The results for Sweden were less useful. ChatGPT 5 did link to *Trafikverket*, the Swedish counterpart of Rijkswaterstaat (Trafikverket, 2019). However, only a small guidance document was found. Translation was again done via Google Translate. So, with the same reasoning as for Slovenia, this guidance document was left out for further analysis.

For Luxemburg, no official information was found, only an official application form for a permit was found. ChatGPT 5 did link to this specific webpage on the government website (Le Gouvernement, 2025), but after translating and manual screening of the website, no further relevant information was found. Luxemburg was thus also left out for further analysis.

4.2. Official information

The reviewed best practices are from: Denmark; Finland; France; New Zealand; Norway; Switzerland; United Kingdom.

4.2.1. Placement

Every reviewed document covered placement criteria of roadside advertising. Although the level of detail varies, every reviewed document this as first criteria, indicating the importance of the location of an advertisement. Both France and Switzerland were very clear regarding placement along highways and motorways; here, roadside advertising is prohibited (Legifrance, 2014; Kanton Bern, 2022). Although therefore a comparison to the Dutch assessment framework is not really possible, since the Dutch framework is just about highways and motorways, France and Switzerland are still reviewed to identify potential new insights or used as analogy from guidelines regarding smaller roads.

4.2.1.1. Meters outside of the roadway

Firstly, the lateral distance to the road is covered by all reviewed documents. In Finland there is a distinction made between motor- and expressways (the largest roads, with higher speed limit) and highways (road where the speed limit is slightly lower). Speed limits of these two categories of roadways are not mentioned, but for the motor- and expressways the lateral distance should be *at least* 50 meters from the center of the outer carriageway (Traficom, 2019). So, for example, a motor- or expressway has three carriageways, and an advertisement is to be placed on the right side of the road, this advertisement should be placed 50 meters outside of the center of the right carriageway. In Denmark and Norway, another approach is used. Here, the viewing angle is used as starting point. First, an advertisement should be placed outside of the safety zone. Secondly, the advertisement should be *within* a 20-degree viewing angle of the driver. This angle is measured from the moment the advertisement would become visible for a driver. This means that an advertisement may not be placed too far out of the roadway. The United Kingdom does not have specific details but mentions that advertisements which are not placed with sufficient clearance of the road, both lateral and vertically, may cause danger to road users. What sufficient clearance should be, is not specified (Gov.uk, 2019).

Secondly, the vertical distance is covered by some of the reviewed documents. Switzerland mentions a minimum of 4,5 meters of elevation, with again the note that this does concern high- and motorways, as advertising is prohibited on these roads (Kanton Bern, 2022). New Zealand's guidance mentions that placement above the roadway is prohibited but the guidance document does not mention a minimum height for billboards outside the roadway (NZTA, 2025).

4.2.1.2. Viewing angle

This criterion is not studied in (recent) literature but is included in some guidelines. Denmark and Norway mention that the angle of which an advertisement is viewed should be between 60 and 90 degrees, where 90 degrees is perpendicular to the direction of travel (Vejdirektoratet, 2015; 2018) (Statens vegvesen, 2021). Fun remark is that Denmark uses 120 degrees as number, and Norway uses 60, while they mean exactly the same angle. New Zealand advises different angles for different speed limits in their guidance document. For roads up to 50 km/h, an angle between 30 and 90 degrees can be allowed, for up to 75 km/h, this can be 42,5 – 90 degrees, and for up to 100km/h this angle is narrowed to 55 – 90 degrees (NZTA, 2021). Finland, France, Switzerland and the United Kingdom do not mention viewing angle in their information.

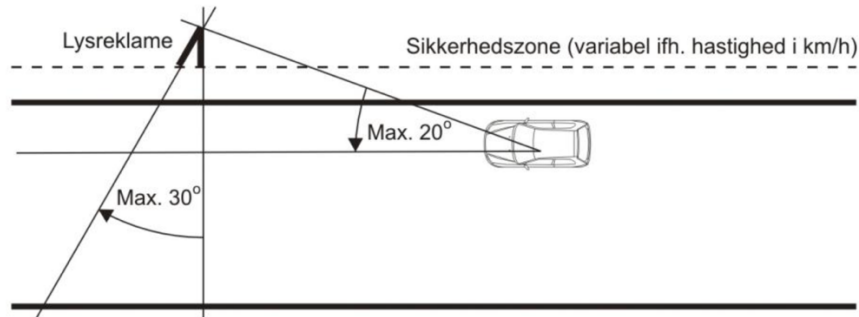


Figure 13: Illustrated example of viewing angle in Danish guidance document (Vejdirektoratet, 2018)

4.2.1.3. Intersections

The United Kingdom states that it should be considered that at junctions and roundabouts, advertisements are more likely to affect public safety (Gov.uk, 2019). No strong conclusion is drawn from this, while Norwegian and New Zealand information is for example more clear: roadside advertisement should not be placed at intersections (Statens vegvesen, 2021; NZTA, 2021; 2025). Switzerland states that advertisements should not be placed in the vicinity of junctions, intersections or entrances and exits (Kanton Bern, 2022). Denmark makes a distinction between different sizes of intersections. For major intersections, where there are 3 or more lanes for each direction, advertising must not be placed. For smaller intersections, it depends on the combination with other driving aggravating circumstances (Vejdirektoratet, 2015; 2018).

4.2.1.4. Curved roads

For curved roads, both the horizontal and vertical alignment is considered. Denmark, Finland, Norway and Switzerland all mention tunnels as location where advertising is not allowed. Switzerland only mentions tunnels and does not mention bridges. Denmark and Norway do not mention a specific distance but state that advertisements must not be placed just before or after tunnel openings and bridges (Vejdirektoratet, 2015; 2018) (Statens vegvesen, 2021). Finland specifies this with a distance of 200 meters before and after a tunnel and 50 meters before or after a bridge (Traficom, 2019). Both Denmark and Norway also mention hill peaks as locations where roadside advertising should not be placed.

For horizontal alignment, the United Kingdom state that advertisements which obstruct or impair sight-lines at corners or bends, may cause danger to road users. Denmark specifies this with stating that roadside advertising should not be placed in curves with a radius smaller than 400m. New Zealand uses chevron boards as a benchmark for tight curves. If a curve does have chevron boards, no roadside advertising is allowed (NZTA, 2021; 2025).

4.2.1.5. Blocking vision

The official information of the different countries is consentient when it comes the vision on the road and traffic information of road users. An advertisement must not obstruct the view of traffic signals, signs or road markings (Statens vegvesen, 2021) (Vejdirektoratet, 2015; 2018) (NTZA, 2025). This is because blocking traffic signs or signals could be dangerous (Gov.uk, 2019). In Finland too, advertisements are not allowed on places where it obstructs traffic signs or road marking or impairs the detection of these signs (Traficom, 2019). For illuminated advertisements, the Danish assessment framework stated that the distance to traffic signs should be enough to see the traffic sign for 5 seconds without seeing advertisements. A table is provided with distances for different speed limits to ensure a 5-second reading time. E.g. for a road with a speed limit of 90 km/h, the distance for an advertisement to a traffic sign should be no less than 125 meters (Vejdirektoratet, 2015; 2018).

At the same time, the vision of a road user with regard to the advertisement is covered quite detailed in both the Danish and Norwegian guidelines. The advertisement must be fully visible for at least 5 seconds, in order to read and understand the advertisement as quickly as possible (Vejdirektoratet, 2015; 2018). To determine a corresponding distance for this visibility time of 5 seconds, Norway uses a metric related to the size of the advertisement. The largest dimension of an advertisement is taken, which is the diagonal for a rectangular shaped advertisement, and multiplied by either 10 or 15, depending on the speed limit (50-60 km/h and 70-90 km/h respectively) (Statens vegvesen, 2021). This results in a distance for which an advertisement should be fully visible. Denmark mentions and adapted this metric but also provide the earlier-mentioned table with fixed minimum distances for different speed limits as backup (Vejdirektoratet, 2015; 2018).

4.2.1.6. Speed

Speed limits are mentioned by Denmark with regard to other driving aggravating circumstances. Roadside advertising is not allowed on high-speed roads where too many driving aggravating circumstances are present. The degree of driving aggravating circumstances can be higher for low-speed roads. The Danish advisory guidelines make use of a point system where driving aggravating factors are awarded points. For example, how busy a road is. Road that (often) are on 80% or higher of their maximum road capacity, or are known to have congestions problems, are given 0 points. Roads with a load of 60 to 80% are awarded 1 point, and roads with less than 60%, the quiet roads, are awarded 2 points. This congestion assessment is only one of five driving aggravating conditions. After a road is assessed on all five conditions, a number of points between 0 and 10 is scored. For high-speed roads, (≥ 90 km/h) roadside advertising is only advised if the road scored 9 or 10 points. For roads with a speed limit higher than 60 km/h, this should be at least 6 to 8 points and for roads with a speed limit up to 60 km/h, at least 5 points should be scored (Vejdirektoratet, 2015; 2018).

New Zealand uses 80km/h as a dividing line for approval of digital billboards. On roads with a speed limit higher than 80 km/h, digital billboards won't be approved by the NTZA and on roads with a speed limit lower than 80 km/h, there will be decided on a case-by-case basis if a digital billboard is suitable or not (NZTA, 2025).

4.2.1.7. Turbulence zone

In Denmark, roadside advertising should not be placed on roads that have 4 or more entrances or exits per 500 meters. These roads score 0 points for this driving aggravating condition. Roads with 2-4 entrances or exits per 500 meters score 1 point. Less than 2 exits or entrances results in 2 points (Vejdirektoratet, 2015; 2018). New Zealand is quite clear and mentions that digital billboards should be placed away from turbulence zones (NZTA, 2025). In the Finnish guidelines it is mentioned that advertisements may not be placed less than 200 meters before the first interchange sign. On the interchange itself, advertising is also prohibited (Traficom, 2019).

4.2.1.8. Clutter

In terms of clutter, advertising should not be placed nearby famous monuments or other eye-catchers (Vejdirektoratet, 2015; 2018). The same applies for Norway, but their guidelines add that only a limited amount of advertisements should be in the field of view of a driver at once (Statens vegvesen, 202). Finland does not mention eye-catchers but stated that an advertisement should not be placed within 100 meters of any other roadside advertisement (Traficom, 2019). New Zealand also mentions that a minimum distance between digital billboards should be used, where a differentiation is made for different speeds (NZTA, 2025), where on roads up to 70 km/h, the spacing between digital billboards should at least be 160 meters.

4.2.2. Dwell time

In the Norwegian guidelines, changeable advertisements are covered by: *“Advertising where the content and message change more often than once a day is prohibited along roads outside built-up areas.”* (Statens vegvesen, 2021, p. 12), which is quite clear. Inside built-up area, only on low-speed roads, may changeable advertisements be permitted under certain conditions (Statens vegvesen, 2021). Switzerland does mention different dwell times, but as these are not for advertisements along highways, where the Dutch framework is about, these Swiss dwell times are not discussed here (SVI, 2016; Kanton Bern, 2022). This is because dwell times on low-speed roads are incomparable to those on highways.

The United Kingdom only mentions that frequent changes of the display may cause danger to road users, but no dwell time or transition details are mentioned.

Denmark mentions that regarding changeable illuminated advertising screens, the starting point is that road users see no more than one advertisement per passing vehicle. As for detailed dwell times, it is mentioned that these should be at least 6 seconds, or 10 seconds for roads with multiple advertisements (Vejdirektoratet, 2015; 2018). However, it is not mentioned how many advertisements per distance there should be, in order to have 10 second dwell time as benchmark. For example, it can now be interpreted as that a road of 30 kilometer can have two advertisements and therefore should be using a dwell time of 10 seconds. This highlights a gap in the Danish assessment framework.

In Finland, the dwell time for changeable advertising is not distinctive for different types of roads; a minimum dwell time of 30 seconds is used for every road (Traficom, 2019), which can be considered quite high.

New Zealand uses a system to assess the right dwell time for different locations. 10 seconds is chosen as the baseline; every digital billboard should have a dwell time of at least 10 seconds. On top of those 10 seconds, there will be 10 seconds added for every driving aggravating circumstance, varying from turbulences zones, exceeding the desired maximum display size, known dangerous locations, and several other site-specific complexities; a complete overview is provided in Figure 14. After a dwell time is constructed, it is stated that there should be checked against the principle that most drivers see only one image, and thus no changes (NZTA, 2025).

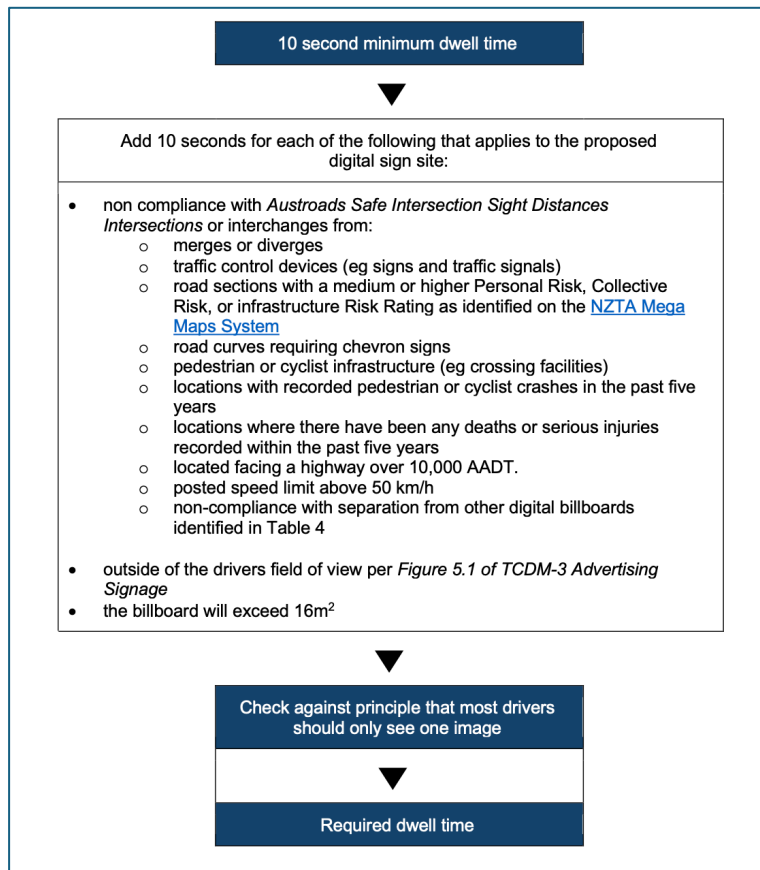


Figure 14: Dwell time assessment calculation (NZTA, 2025)

4.2.2.1. Transition

The countries analyzed have different views on transition between images. New Zealand uses a maximum dwell time of half a second and no special effects are allowed. The change in luminance between two images may not be more than 30% (NZTA, 2025). In Denmark, the transition should also be without any visual effects, and it may take maximal one second to transition one image into another (Vejdirektoratet, 2015; 2018). This is done differently in Finland. Here, the following is mentioned: *“The change of advertisement must not occur by flashing directly to the next advertisement or through a short dark state, but the previous advertisement must fade out slowly over a period of approximately two seconds and the next one must come on over a period of approximately two seconds. Alternatively, the change of the previous and next advertisement can be implemented by overlapping by sliding from top to bottom or from left to right over a period of approximately two seconds.”* (Traficom, 2019, p. 5).

4.2.3. Sign type

Apart from illuminated advertisements and changeable advertisements, the reviewed frameworks do not make major type-based distinctions. There are no specific guidelines for the placement or content between banners or static billboards for example. The only found distinction is made on the construction of different types of sign types.

Finland, Denmark, New Zealand and Norway all four mentions that elements or materials that are reflective, e.g. mirrors, must not be used in the construction of the advertising mast, as this could cause glare (Vejdirektoratet, 2015; Traficom, 2019; Statens vegvesen, 2021; NZTA, 2025). The Norwegian guidelines go one step further. The non-advertising part of the roadside advertising object, for example, the pole where a screen is attached to, must consist of neutral colors. Black, grey or brown are given as examples of neutral colors (Statens vegvesen, 2021).

Banners and flags are mentioned specifically in the Danish and Norwegian guidelines, with regard to attachment. These smaller, and often temporary signs, should be attached securely, so that they can handle strong winds (Vejdirektoratet, 2015; Statens vegvesen, 2021).

4.2.4. Illuminance

Illuminated advertising can be categorized into two types: illuminated signs and self-illuminated signs. Illuminated signs are lit by lamps or spotlights, whereas self-illuminated signs are the screens that are lit from within, by LEDs for example.

In Denmark, illuminated signs must be able to regulate brightness with relation to surroundings. No further details are provided on how this regulation of luminance should be implemented (Vejdirektoratet, 2018). By Norwegian guidelines, roadside advertising also should not have a brightness level higher than the brightness of elements in its surroundings (Statens vegvesen, 2021). The United Kingdom stays even more superficial, stating that illuminated advertisements that can result in glare and/or dazzle, due to their size and/or brightness, may cause danger. Wherefore, this should be considered by municipalities or road agencies by assigning a permit (Gov.uk, 2019).

In Finland, illuminated signs (by lamps or lights) should be evenly lit, so that there are no (much) brighter spots on the surface. The luminance of advertising signs should be lower than reflective traffic signs. Also, both illuminated signs as self-illuminated advertisements (screens) should not be turned on and off periodically (Traficom, 2019). In France and New Zealand, all digital advertising devices must be equipped with a dimming system to adapt the lighting to the ambient brightness (Legifrance, 2014; NZTA, 2025).

4.2.4.1. Rural and urban roads

A clear distinction between rural and urban roads is not made in the reviewed documents, but Finland and Norway both covered roads that are unlit. On these often-rural roads, where no street lighting is placed, Norway states that no illuminated advertising should be placed. However, for on-premise advertising, exemptions can be made (Statens vegvesen, 2021). Finland mentions that self-illuminated (digital) roadside advertising is prohibited on these unlit roads (Traficom, 2019).

4.2.4.2. Daytime and nighttime

Norway and Finland are again the only two countries that covered some details regarding nighttime. During dark, illuminated advertisements should not be turned off and on (Statens vegvesen, 2021). Finnish guidelines state that during dark, self-illuminated advertisements should not exceed luminance of 300 cd/m², while at dusk, luminance should not be more than 5 times its ambient luminance. Advertisements should be able to adjust its brightness automatically, based upon the luminance of its surrounding (Traficom, 2019). Although the French guidance applies more for cities and urban low-speed roads, there is an interesting insight; all illuminated advertising signs must be switched off during nighttime (01:00 and 06:00) in municipalities of 800.000 inhabitants and less (Legifrance, 2014). This can be seen as a regulation against visual pollution, since population plays a role in this guideline.

4.2.4.3. Crash modus

A digital billboard having an error or broken light source is an aspect that is not covered in the current Dutch assessment framework, nor has it been covered in recent literature. However, Denmark and Finland have thought about it. The Danish framework mentions such error situations as a knowledge gap, they for now only state that more investigation is needed on error handling and further state that the operator should ensure that illuminated advertisements functions appropriately (Vejdirektoratet, 2015; 2018).

Finland and New Zealand are more concrete about an error that may occur; when a digital billboard is partially or completely out of order, the advertising object should be turned off (Traficom, 2019; NZTA,

2025). New Zealand also mentions that this should happen automatically, but there also should always be the option to shut down a digital billboard manually (NZTA, 2025).

4.2.5. Sign content

Although Switzerland prohibits the placement of roadside advertising along highways, an exemption for permission can potentially be made for announcements with a traffic education, accident prevention or traffic control character. In this case any logo, text or symbol of the sponsoring organization of the announcement may occupy on no more than one tenth of the area on the board (Kanton Bern, 2022).

4.2.5.1. Color

On this aspect, there is only little guidance, apart from resemblance to traffic information, which is covered in paragraph 4.2.5.7. Denmark does mention that bright colors should be used and that the contrast between used colors should be preferably large. This is preferred in order to lower interpretation times of advertisements. For example, light blue letters on a background that is slightly darker blue, is harder to read than black on white. In Norway, 'sufficient' contrast between text and its background is demanded too (Statens vegvesen, 2021). That being said, the Danish guidelines also mention that large white areas on the advertising surface should be avoided, this to avoid brightness (Vejdirektoratet, 2015; 2018).

An extensive take on sign background and contrast between the message the background on an advertisement is written in the New Zealand's guidelines. There are multiple examples given about desirable and non-desirable backgrounds with regard to contrast (NZTA, 2021).

4.2.5.2. Text

Regarding the overload of the content, due to a lot of text, images, or any other form of content on the advertising surface, Denmark and Norway are the only countries who mention detailed guidance on this content aspect. Denmark and Norway both state that, in total, no more than 8 words, images, symbols or numbers should be displayed on an advertisement along the road (Vejdirektoratet, 2015; 2018) (Statens vegvesen, 2021). New Zealand uses a guideline of maximum 10 elements. This number results from a function of reading speed of a driver and readability distance of a billboard (NZTA, 2025).

The Danish guidelines state that fonts that are used should be easy to read and large enough (Vejdirektoratet, 2015; 2018). The Norwegian guidelines, however, are more specific, mentioning a table with different text heights for corresponding distances. For example, to ensure that a font is large enough to cover a reading distance of 180 meter, a capital letter of at least 420 mm should be used (Statens vegvesen, 2021). New Zealand does provide a table with different text heights for different speed and does differentiate between the type of text; main message must be larger than the secondary message or the property name on an advertisement (NZTA, 2021). The height of the letters is smaller in New Zealand's guidelines than in the Norwegian one, with 300mm being the largest minimum, compared to the mentioned 420mm in Norway (NZTA, 2021). In addition to the text height, both Norway and New Zealand give clear examples of different fonts styles that are easy and difficult to read (Statens vegvesen, 2021; NZTA, 2021).



Figure 15: Norwegian example of fonts difficult to read (Statens vegvesen, 2021)

4.2.5.3. Images and video

Following the Danish guidelines: static images should be easy to decode, and displaying moving images is prohibited on digital advertising objects (Vejdirektoratet, 2015; 2018). Finland is also quite clear regarding moving images, these are prohibited, just as flashing effects (Traficom, 2019). The United Kingdom does mention that danger to road users is imposed by moving element, and this thus needs to be prevented (Gov.uk, 2019). As mentioned earlier, in Norway, changeable advertising is prohibited, so this also applies for moving images. New Zealand's guidance is in line with abovementioned countries, prohibiting video and images, flashes and any form of animation. In addition, New Zealand is the only country which mentions that the use of audio from billboards is also prohibited (NZTA, 2025).

4.2.5.4. Emotionally loaded content

An advertisement should not contain messages, in the form of both text and images, that can arouse strong emotions or may fear people (Vejdirektoratet, 2015; 2018; Statens vegvesen, 2021). The impact of an emotional message should therefore be considered (NZTA, 2025). Finland, France, Switzerland and the United Kingdom do not mention this aspect.

4.2.5.5. Level of expectancy

The sequencing of advertisements is covered by the documents of Denmark, New Zealand and the United Kingdom, where all conclude that successive individual images, which in itself do not display a complete message, is unwanted and may cause danger to road users (Vejdirektoratet, 2015; 2018; Gov.uk, 2019; NZTA, 2025). Although in Norway, changeable advertisements are prohibited, there is still included in their guidelines that an advertisement should be an independent and complete message (Statens vegvesen, 2021). This is done to prevent that a neighboring advertisement can contain a follow-up message.

In order to help road users understand and interpretate roadside advertisements as quickly as possible, Norway and Denmark state that an advertisement should be fully visible, just as mentioned in paragraph 4.2.1.5. Another aspect of expectancy that both Norway and Denmark share, together with New Zealand, is that advertisements may not contain phone numbers, QR codes, e-mail addresses, questions, riddles, or website links (Vejdirektoratet, 2015; 2018; Statens vegvesen, 2021; NZTA, 2025). All of these content parts implicitly encourage further action for the road user to undertake. Following this, also explicit call-to-actions are prohibited. E.g. 'TEXT TO ... FOR ...' (Vejdirektoratet, 2018).

4.2.5.6. Size

As the size of an advertising object in itself may cause confusion and/or distraction and may impose danger for road users, it is stated in Denmark, Norway and the United Kingdom that advertisements must not be strikingly large (Vejdirektoratet, 2015; Gov.uk, 2019; Statens vegvesen, 2021). However, in the official information of these three countries there are no specifications or maximum dimensions given. Finland does have a fixed maximum size for advertisements, which is 50 m².

4.2.5.7. Resemblance to traffic information

All reviewed documents mention that advertisements may not potentially be confused for official traffic signs, messages or information. Advertisements should not contain signals or guiding elements such as a 'stop' logo or arrows (Vejdirektoratet, 2015, Gov.uk, 2019; Traficom, 2019; Statens vegvesen, 2021; Kanton Bern, 2022; NZTA, 2025). Also using the same colors (red, orange, green) or same shapes (e.g. triangles, circles or crosses) as traffic signs and signals is prohibited.

4.2.6. Landscape and Spatial quality

This aspect received little to no attention in the official information that has been reviewed. Apart from the luminance guidelines of Norway and Finland about prohibiting illuminated advertising along unlit roads, which can implicitly be read to prevent visual pollution. However, main reasoning behind these two guidelines is that glare and dazzle are prevented to form a driver distraction. Regarding visual pollution, France does prohibit the placement of illuminated advertising in municipalities smaller than 800.000 inhabitants, and advertising as a whole in municipalities smaller than 10.000 inhabitants, with exceptions (Legifrance, 2014).

One of few remarks on landscape and spatial quality was found in a Danish document. This document contained section 21 of the Danish Nature Protection Act. Here, it is stated that roadside advertising is prohibited in open countryside. Only small on-premise signs are mentioned to be permitted. Examples are signs about the sale of vegetables or Christmas trees that are grown and sold on the corresponding property (Retsinformation, 2021). The French guidelines further mentions that on buildings with historical status, as well as in the vicinity of national parks, advertising is prohibited (Legifrance, 2014). New Zealand's guidance document is superficial, stating that the "NZTA seeks to minimize visual impacts on surrounding sensitive environments and reduce visual clutter." (NZTA, 2025, p. 16).

4.3. Discussion

4.3.1. General remarks

What stood out during the comparison analysis, was that the introduction of each of the guidance documents was quite clear. Most countries did specify the different types of advertising, and several countries did mention the legal basis of their guidelines, referring to articles and sections of corresponding road laws. The Norwegian document for example, starts with an extensive definition and examples of roadside advertising and what is (not) considered in their information document. I.e. trailers with banners that are clearly intended to be visible for advertising purposes is also treated as advertising (Statens vegvesen, 2021).

When reviewing the different guidance documents, it was sometime explicitly, but more often implicitly stated that the guidelines were based on scientific research. New Zealand did have an extensive literature review, mentioning a broad set of known and often recent scientific articles from the field of roadside advertising and driver distraction (NZTA, 2025). Their literature review contains reviewed literature on self-regulation (after being exposed to a digital billboard), crash data analysis, and multiple driving effects, such as lateral control, headway control, gaze behavior, response time, error increase, approach seeds. There is also reflected on the research complexity of this topic (NZTA, 2025). After the literature review, the sections with guidelines are written. Here, the scientific fundament is again noticed, as per guideline, it is made clear which sources are used as reasoning for the guideline. For the reviewed best practices and their scientific fundament, New Zealand could be seen as a textbook example. Norway for example, it could be read between the lines that the guidelines are based on scientific principles, but not a single reference is made (Statens vegvesen, 2021). The same applies for Denmark. These two countries both use a schematic graph on the task capability principle. When the driving task (red line) becomes more demanding than the capability of the driver (green line) at that moment, crashes occur (Vejdirektoratet,

2018). This task-capability model has been used in Oviedo-Trespalacios et al. (2019) as structural basis for their literature review.

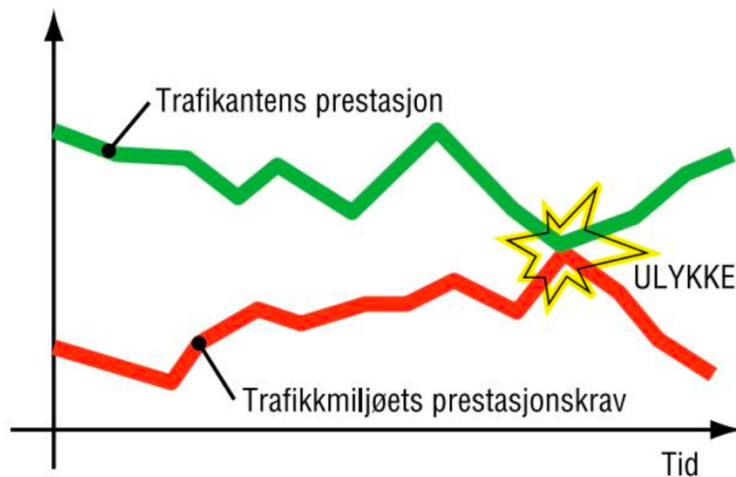


Figure 16: Norwegian graph on Task-Capability model (Statens vegvesen, 2021). When the demands the road system (red line) exceeds the capability of the road user (green line), crashes occur.

Another general remark is that the reviewed official information did make significant use of images and illustrations. When different types of advertising are introduced and discussed, images were used in the Norwegian guidelines (Statens vegvesen, 2021). Just as examples on different fonts styles that are easy and difficult to read. When summarizing the placement criteria, Switzerland used clear illustrations in their guidelines (Kanton Bern, 2022). New Zealand used two clarifying examples of billboards with both acceptable and an unacceptable amount of content (NZTA, 2025). Finland and the United Kingdom were the only two exceptions, using no images at all.

4.3.1.1. Other remarks

Denmark, Norway both mentioned that roadside advertising object should experience sufficient maintenance, but in Finland, this is more concrete, stating that placement of roadside advertising is prohibited for locations where year-round maintenance is not possible (Traficom, 2019). Norway had a unique mention by stating that the operator of advertisement object should be placed on the advertising object. This is done so that it is clear who is responsible for maintenance (Statens vegvesen, 2021).

Denmark, Norway and New Zealand mentioned that roadside advertising may not be placed along roads where fatal or high severe crashes have happened in the past five years (NZTA, 2025) or on roads which are known to be accident-prone (Vejdirektoratet, 2015; Statens vegvesen, 2021).

In the Danish, Norwegian and Swiss guidelines there is the assessment and application form enclosed for permit application, at the same time, this serves as a structured overview table. New Zealand also uses a clear overview table in their summary section (NZTA, 2025). This could definitely help the audience that use these guidance documents.

One last small remark is that both Norway and Switzerland both have spent a section on how to cope with illegal advertising. This contains information on when it is allowed for road authorities to directly remove an advertisement and when road authorities should contact the owner first (Statens vegvesen, 2021). However, as this often concern small (on-premise) advertising, this content is less applicable for the Dutch framework, but as a general takeaway, it could be interesting to provide guidance on how to cope with illegal advertising along state roads.

4.3.2. Compared to the Dutch assessment framework

Regarding lateral distance, there are quite some differences between the analyzed countries and the Netherlands. In the Netherlands the minimal placement distance is 13 meters from the outer side of the roadway. A first difference is that Denmark, Norway and Finland do not use the outer side of the roadway but use the center of the roadway/carriageway. Denmark and Norway take the driver seat as measuring point, but it is assumed that the driver seat is roughly in the centre of the carriageway. A second difference is that Denmark and Norway state that an advertisement must not be too far out of the roadway, as this would cause drivers to turn their head towards the advertisement in order to fully see the advertisement (Vejdirektoratet, 2015; 2018) (Statens vegvesen, 2021). This differs from the Netherlands, where no maximum distance is mentioned. Although an interesting difference, scientific literature by Costa et al. (2019) mentions that the bigger the lateral distance, the less fixations. It thus seems that there would be no need to adopt such a maximum offset angle or distance.

Compared to the Netherlands, Denmark and Norway have the same details regarding viewing angle, this should be between 60 and 90 degrees (Rijkswaterstaat, 2019). New Zealand did use a speed-differentiation approach, but as the speeds on Dutch highways and motorways are in the highest speed category, this would not seem as a necessary approach to take over.

For placement in corners, Denmark uses curves with a radius of 400 meters, as lower limit for not allowing roadside advertising. New Zealand uses the presence of chevron boards as indicator whether roadside advertising should be permitted. Chevron boards as indicator does seem plausible and intuitive, however, they are not that common on highways in the Netherlands. The Dutch framework refers to the Dutch Road Design Manual (ROA) for lower limits for radiuses of curves (Rijkswaterstaat, 2019). It would be helpful to mention this or these numbers, so their assessment framework could be read more as a standalone document.

When comparing to other countries, the Dutch framework does cover turbulence zones and driving aggravating road segments extensively. New Zealand does also conclude that roadside advertising should be placed away from merge and diverge zones.

Finland and New Zealand both mention minimal spacing distances between advertising objects, in order to prevent visual clutter. The Dutch framework currently does not mention this level of detail.

Dwell time is done differently in every country. From prohibition in Norway to a fixed minimum of 30 seconds in Finland to an extensive checklist based on different driving aggravating circumstances in New Zealand. Denmark and New Zealand both explicitly mentioned a guiding principle that drivers should be able to see a maximum of one image change. A unique insight is that the Netherlands is the only reviewed country that differentiates based on rush hour. As rush hour can also be seen as a driving aggravating circumstance, this can be seen as a valid choice. Regarding the transitions for image changing, most countries are one the same page as the Netherlands, stating that a quick transition without special effects is desired. Finland seems to be an exception, rather than a good example of best practice, by stating that a transition should be done slowly and use a sliding effect.

The regulation of luminance is quite clear in the Netherlands, presenting an overview table with different circumstances and different light emission levels. Norway, Finland and France mention the luminance output at night, where France has the most unique insight. Their guidelines state that between 1am and 6am, all illuminated should be turned off. Apart from road safety, the prevention of visual pollution is a reason in their guidance. In the Dutch framework, it is also mentioned that, for visual pollution reasons, illuminated advertising may be turned off during nighttime.

It was refreshing to see that Denmark, Finland and New Zealand presented guidance on potential malfunctioning of (digital) billboards. There should be the ability to automatically shut a digital billboard down in case of a malfunction. The Netherlands does not cover this. However, this could be helpful to include.

Regarding sign content, other countries were found to be more detailed of the amount of content that is allowed to be displayed. A maximum of total words or elements is used in other countries. For example, 8 elements (e.g. words, images, logos, etc) are included in the guidelines of Norway and Denmark and a maximum of 10 elements in New Zealand. Font sizes as well as font types were illustrated by clear examples by Norway and New Zealand. The contrast and use of colors that are easy to interpret are also substantiated by example images. The Netherlands does not provide this guidance on sign content, while it could be helpful.

Finland does mention a maximum size of 50 m². Other countries only mention that advertisements must not be strikingly large, in order to prevent distraction from the object itself. The Dutch framework does mention that it should be immediately clear what an object represents, but as size of an advertising object could be distracting in itself (Alkheder et al., 2024), this might be a good addition to the Dutch framework.

4.3.3. Comparing international best practices

In Table 4 and Table 5, there is an overview provided of which topics are covered in the analyzed international best practices. An extensive overview table, with the exact information per topic per country, can be found in Appendix B.

In these two tables, it is shown that the Dutch guidelines are on par with the best practices of other well-performing countries. Covering nearly every topic, with supportive threshold or examples. Denmark, Norway, Finland and New Zealand are also comprehensive, as proven by the amount of topics that are mentioned in their guidance documents. On the other hand, Switzerland, as well as the United Kingdom and France, cover less.

The United Kingdom for example mentions dwell time as factor to take into account, as it may cause danger to road users (paragraph 4.2.2), but no details are provided in their guidance document. Hence, only *'mentioned'* is denoted for dwell time for the United Kingdom in Table 5. The United Kingdom does this for the majority of topics, they acknowledge the different safety impairments by roadside advertisements, but do not give concrete guidance on how to cope with these. Contrary, New Zealand does provide clear examples in most cases, making the guidance document rich of illustrations and appealing for stakeholders to read, this also helps in understanding the document. For some criteria, the Dutch guidelines could learn from this. Although the Dutch guidelines are already quite extensive, there could be examples on the amount of text elements or spend a guideline on how to cope with malfunctioning digital billboards.

Table 4: Covered topics and presence of thresholds in international best practices

Country	The Netherlands	Denmark	Norway	Switzerland
Demand of road environment				
Intersections	Mentioned with treshold / example	Mentioned with treshold / example	Mentioned	Mentioned
Curved road	Mentioned	Mentioned with treshold / example	Mentioned	Mentioned
With regard to speed	Mentioned with treshold / example	Mentioned with treshold / example		
Blocking vision	Mentioned	Mentioned with treshold / example	Mentioned with treshold / example	
Turbulence zone	Mentioned with treshold / example	Mentioned with treshold / example		
Clutter	Mentioned	Mentioned	Mentioned	Mentioned
Placement				
Angle of viewing the billboard	Mentioned with treshold / example	Mentioned with treshold / example	Mentioned with treshold / example	
Meters outside of the roadway	Mentioned with treshold / example	Mentioned with treshold / example	Mentioned with treshold / example	
Sign type		Mentioned	Mentioned with treshold / example	
Illuminance				
Rural vs urban	Mentioned with treshold / example	Mentioned	Mentioned with treshold / example	
Day vs night	Mentioned		Mentioned with treshold / example	
crash modus	-	Mentioned		
Sign content				
Color	Mentioned	Mentioned	Mentioned	
Text	Mentioned	Mentioned with treshold / example	Mentioned with treshold / example	
Images	Mentioned with treshold / example	Mentioned		
Video	Mentioned with treshold / example	Mentioned with treshold / example		
Emotionally loaded content	Mentioned with treshold / example	Mentioned	Mentioned	
Level of expectancy	Mentioned	Mentioned with treshold / example	Mentioned with treshold / example	
Size	-	Mentioned	Mentioned	
Resemble to traffic information	Mentioned with treshold / example	Mentioned	Mentioned	Mentioned with treshold / example
Dwell time	Mentioned with treshold / example	Mentioned with treshold / example	Mentioned with treshold	
Transition	Mentioned with treshold / example	Mentioned with treshold / example		
Landscape and spatial quality	Mentioned	Mentioned		

Table 5: Covered criteria and presence of thresholds in international best practices

Country	United Kingdom	Finland	France	New Zealand
Demand of road environment				
Intersections	Mentioned			Mentioned
Curved road		Mentioned with treshold / example		Mentioned with treshold / example
With regard to speed				Mentioned with treshold / example
Blocking vision	Mentioned	Mentioned		Mentioned
Turbulence zone		Mentioned with treshold / example		Mentioned
Clutter		Mentioned with treshold / example		Mentioned with treshold / example
Placement				
Angle of viewing the billboard				Mentioned with treshold / example
Meters outside of the roadway	Mentioned	Mentioned with treshold / example		Mentioned with treshold / example
Sign type		Mentioned	Mentioned	Mentioned
Illuminance				
Rural vs urban	Mentioned	Mentioned with treshold / example		Mentioned with treshold / example
Day vs night		Mentioned with treshold / example	Mentioned with treshold / example	Mentioned with treshold / example
crash modus		Mentioned with treshold / example		Mentioned with treshold / example
Sign content				
Color				Mentioned with treshold / example
Text				Mentioned with treshold / example
Images				Mentioned with treshold / example
Video	Mentioned with treshold / example	Mentioned with treshold / example		Mentioned with treshold / example
Emotionally loaded content				Mentioned
Level of expectancy	Mentioned			Mentioned with treshold / example
Size	Mentioned	Mentioned with treshold / example		Mentioned with treshold / example
Resemble to traffic information	Mentioned with treshold / example	Mentioned with treshold / example		Mentioned with treshold / example
Dwell time	Mentioned	Mentioned with treshold / example		Mentioned with treshold / example
Transition		Mentioned with treshold / example		Mentioned with treshold / example
Landscape and spatial quality			Mentioned	Mentioned

5. Crash data analysis

5.1. Results

All crashes in the influence zone were counted for each of the treatment sites, as well as all the crashes in the control site. As discussed in chapter 2.3.1, the same control site has been used for every treatment site, only the placement or digitization differs for each treatment site. Hence, the different number for the control site, as can be seen in Table 6. One billboard did not have a single observed crash in the before period. This billboard is left out for further analysis, as it is impossible to calculate an odd-ratio with these crash numbers.

Without this billboard, 20 analyzed digital billboard remained. Out of these, 16 were static billboards in the before period and digitized in the intervention year. The other four digital billboards did not exist in the before period, as they were built in the intervention year. The estimated effect (odd-ratio), the weight of the effect, the estimated safety effect (as a percentage) and its corresponding limits at the 95%-confidence interval is presented in the table below. In the last column, it is shown whether the estimated effect is of statistical significance. As described in chapter 2.3.2, there is a statistically significant effect when the lower and upper limits of the 95%-confidence interval are both on either the positive or negative scale.

Table 6: Results per billboard

Billboard	Intervention		Treatment site		Control site		Estimated effect (θ)	ln(θ)	Weight	Estimated safety effect	Lower limit 95% CI	Upper limit 95% CI	Statistical significance
	Year	Type	Before	After	Before	After							
RM008GBB	2020	DIGITIZED	69	23	116787	55167	0,706	-0,349	17,24	29,4%	-13,1%	56,0%	No
RM013GBA	2018	DIGITIZED	53	26	91932	75852	0,595	-0,520	17,44	40,5%	4,9%	62,8%	Yes
RM035GBA	2019	DIGITIZED	17	12	104131	63196	1,163	0,151	7,03	-16,3%	-143,6%	44,5%	No
RM037GBA	2021	DIGITIZED	35	5	124816	45245	0,394	-0,931	4,37	60,6%	-0,6%	84,6%	No
RM037GBB	2021	DIGITIZED	0	6	124816	45245	This billboard is left out for analysis due to unusable crash data						
RM039GBB	2017	DIGITIZED	16	10	63393	88051	0,450	-0,799	6,15	55,0%	0,8%	79,6%	Yes
RM040GBB	2019	DIGITIZED	41	21	104131	63196	0,844	-0,170	13,88	15,6%	-42,8%	50,1%	No
RM050GBB	2017	DIGITIZED	30	73	63393	88051	1,752	0,561	21,25	-75,2%	-168,0%	-14,5%	Yes
RM062GBB	2018	DIGITIZED	26	15	91932	75852	0,699	-0,358	9,51	30,1%	-32,0%	63,0%	No
RM069GBA	2017	DIGITIZED	15	16	63393	88051	0,768	-0,264	7,74	23,2%	-55,3%	62,0%	No
RM077GBB	2018	DIGITIZED	25	17	91932	75852	0,824	-0,193	10,12	17,6%	-52,6%	55,5%	No
RM098GBA	2019	DIGITIZED	29	11	104131	63196	0,625	-0,470	7,97	37,5%	-25,1%	68,8%	No
RM106GBB	2018	DIGITIZED	74	43	91932	75852	0,704	-0,351	27,18	29,6%	-2,6%	51,6%	No
RM107GBA	2018	DIGITIZED	69	47	91932	75852	0,826	-0,192	27,94	17,4%	-19,6%	43,0%	No
RM107GBB	2018	DIGITIZED	22	26	91932	75852	1,432	0,359	11,91	-43,2%	-152,7%	18,8%	No
RM108GBB	2018	PLACED	4	2	91932	75852	0,606	-0,501	1,33	39,4%	-230,9%	88,9%	No
RM109GBA	2017	PLACED	49	43	63393	88051	0,632	-0,459	22,89	36,8%	4,8%	58,1%	Yes
RM109GBB	2017	PLACED	101	73	63393	88051	0,520	-0,653	42,32	48,0%	29,7%	61,5%	Yes
RM111GBA	2019	PLACED	39	38	104131	63196	1,605	0,473	19,24	-60,5%	-151,0%	-2,7%	Yes
RM116GBA	2019	DIGITIZED	2	20	104131	63196	16,477	2,902	1,82	-1547,7%	-6949,9%	-285,1%	Yes
RM116GBB	2019	DIGITIZED	46	16	104131	63196	0,573	-0,557	11,87	42,7%	-1,2%	67,6%	No

When looking at the crash numbers for treatment sites, in the fourth and fifth column, it can be seen that the numbers are small. The use of small data leads to results that are not plausible to conduct analysis on. The crashes in the influence zone of digital billboard RM108GBB for example, are respectively 4 and 2 in the before and after period. On the individual level, there is no statistically significant effect found for two-third of the analyzed treatment sites. The confidence intervals are large for every single treatment site and often ranged from negative to positive. Seven estimates showed statistical significance, three negative safety impact and four showed a positive safety impact.

Table 7: Aggregated safety estimates

Type	PLACED	DIGITIZED
Number of billboards	4	16
WME	0,707	0,835
Estimated safety effect	29,3%	16,5%
Lower limit 95% CI	12,6%	4,2%
Upper limit 95% CI	42,8%	27,2%
Statistical significance	Yes	Yes

When aggregating the results by using the Weighted Mean Effect, more stable effect is found. In Table 7, these aggregated results and their confidence intervals are displayed. Both estimated showed statistical significance, for having a positive safety impact. This would mean that the placement of a digital billboard and digitization of a static billboard, reduces the number of observed crashes in its vicinity. Which is counter-intuitive with the literature review. The results of the analysis can partially be explained by the fact that the influence of a digital billboard is small, resulting in small numbers of observed crashes and a lot of potential room for confounding factors in this influence zone. For the control group, these confounding factors are corrected for by having a large control site, this is not the case for the treatment site (Elvik, 2002). Although the influence zone of the analyzed billboards was drawn with care, a positive aggregated effect can therefore be caused by other factors, influenced by random fluctuation on a yearly basis, and/or be influenced by regression-to-the-mean bias (Elvik, 2002).

5.2. Discussion

In this data analysis, the safety impact of the placement of a digital billboard is examined, as well as the impact of the digitization of a static billboard into a digital billboard. Crash data on Dutch highways was observed for the influence zone of 21 digital billboards and for the whole state road network of the Netherlands. The latter functioned as control group.

The observed safety estimates should be carefully interpreted and cannot be seen as unequivocal evidence for enhancement of road safety by digital advertising objects. After all, in this analysis, it is found that, on an aggregated basis, the observed crashes in influences zone were lower than expected on basis of the comparison group. Although the influence zones were drawn as specific as possible, it remains a pragmatic approach and these observations in crash reduction are not directly attributable to the presence of digital billboards.

There are multiple methodological limitations in place, as the use of small crash numbers. In addition, these analyzed crash numbers come from police reports, Rijkswaterstaat and MobielSchadeMelden (VIA, 2025). There could be potential for under-reported data on low severity crashes (Oviedo-Trespalacios et al., 2019). Also, most of the digital were static billboard in the before-period, which have a distraction factor as well, potentially impacting road safety (Brome et al. 2024). Another limitation is that no specific control groups are used, but only one large control group, for the whole state road of the Netherlands. This was chosen as this was a pragmatic approach and it is assumed that this displays the general trend of road safety in the Netherlands and accounts for confounding factors well enough. However, it could be that the road safety in for example Noord-Holland increased significantly more than in the rest of the country. Although this could be far-fetched, it should be recognized that crashes occur as part of a road safety system, which comes with context-specific environments.

The Dutch context is that one of a well-performing, strongly regulated system (Wegman & Oppe, 2010). Although this does not directly explain the obtained *positive* safety effect, it could be a plausible reason that no estimated negative impact is showed by the data. Which would be expected based on existing literature on safety performance indicators. One explanation could therefore be that the Dutch safety system is found be rigid enough for potential safety impacts by roadside advertising. Another explanation could be that there is a selection effect present; digital billboards are only placed or digitized in locations that are considered sufficiently safe. If this selection for safe locations is done correctly by the stakeholders in the system (i.e. municipalities, advertisement companies and road agency), this could be a big reason that no decrease in road safety is observed, as the location was safe. This reasoning would point out that the Dutch assessment framework is doing its job, the selection criteria for locations are safe enough. However, the knowledge gap remains. In fact, we do not know to what extent digital billboards impact road safety.

The findings of this before-and-after study are in line with previous studies. Sisiopiku et al. (2015) did find a statistically significant *negative* safety effect, where this current analysis obtained a *positive* effect. However, on the individual level, the results in Sisiopiku et al. (2015) were inconsistent and often not significant, similar to this thesis' analysis. Yannis et al. (2013) and Izadpanah et al. (2014) did also found widely varying confidence intervals at the individual level, concluding that no significant safety effect can be determined.

The only exception remains to be the study by Gitelman et al. (2019). The abovementioned studies are focused on the safety impact of individual billboards. However, the methodological difference to the study of Gitelman et al. (2019) is that, due to policy-context of a ban on roadside advertising, it was possible to observe crashes over time on the same large highway. First with advertisements, then without a single advertisement and again with advertisements. Both effects of removing and placing advertisements were statistically significant (Gitelman et al., 2019). This policy-window of opportunity is rare, which makes it unfeasible to replicate this study design.

6. Conclusions

6.1. Discussion

6.1.1. Knowledge gaps

In previous studies and literature overviews, it was already concluded that roadside advertising is in essence distracting and does have the potential to have a negative safety impact (Megías et al., 2011; Oviedo-Trespalacios et al., 2019). To mitigate these potential safety effects, policy guidelines are in place in most countries. It is agreed upon that these guidelines should be preferably based on a solid evidence-base (Rempel et al., 2014). This thesis is about the Dutch assessment framework for guidance of roadside advertising. As the Dutch framework were last revised in 2019, this thesis aims to gain insight in how this Dutch assessment framework could be updated. To come to a conclusion, three knowledge gaps are discussed in this section.

1. The Dutch guidelines are partially grounded by (scientific) literature, however, for some guidelines the framework relies on expert judgement, rather than scientific consensus or consistent guidance. Although this does not seem problematic, there is room for strengthening the evidence-base for roadside advertising and driver distraction, in order to shape and argue for policy guidelines accordingly.
2. Other countries face the same challenge on how to mitigate potential road safety effects along roadways. It is currently unknown how best practices across different countries align. A European comparative study by Boets et al. (2018) showed that the level of detail varies across different countries, this leaves room for updating and aligning the Dutch guidelines by using the best practices from other countries. An overview of guidance documents of other prominent countries on road safety, helps in identifying aspects that the Dutch framework can learn from.
3. Although the potential impact on road safety is acknowledged in existing literature, previous studies has shown that it is very difficult to gain insight in what exact impact roadside advertising has. Conclusive evidence on risk figures is hard to obtain, due to methodological implications. As policymakers are often keen to include qualitative evidence as risk figures into policy guidelines, this leaves a knowledge gap (Oviedo-Trespalacios et al., 2019). By conducting a before-and-after analysis, this thesis aims to gain insight in risk figures due to roadside advertising.

6.1.2. Discussion literature review

During the literature review, 24 articles are analyzed, all published from 2019 until 2025. This time range was chosen because of the publication date of the Dutch assessment framework, which is June 2019. It was therefore assumed that the Dutch framework already used the available evidence-base up to 2019. In this literature review there was sought after new or confirmational insights, so that these insights can be incorporated into the Dutch framework. This helps strengthening the evidence-base.

The analyzed articles all used either driving simulator study (N = 10), naturalistic drives study (N = 4), Secondary simulator data (N = 2), questionnaire data (N = 2), machine learning study (N = 1), attention network test (N = 1) or literature review (N = 6). As this adds up to 26, some studies thus used multiple methods. However, although the demand from policymakers for risk figures exists, crash data analysis has not been found as study type during identifying applicable articles in recent literature.

In recent literature, the focus is on identifying safety performance indicators, such as lane deviation, headway distance and speed regulation, to come to conclusions and recommendations. This is in line with a study to road safety management of Papadimitriou and Yannis (2013). In this study, the SUNflower pyramid is used as theoretical framework.

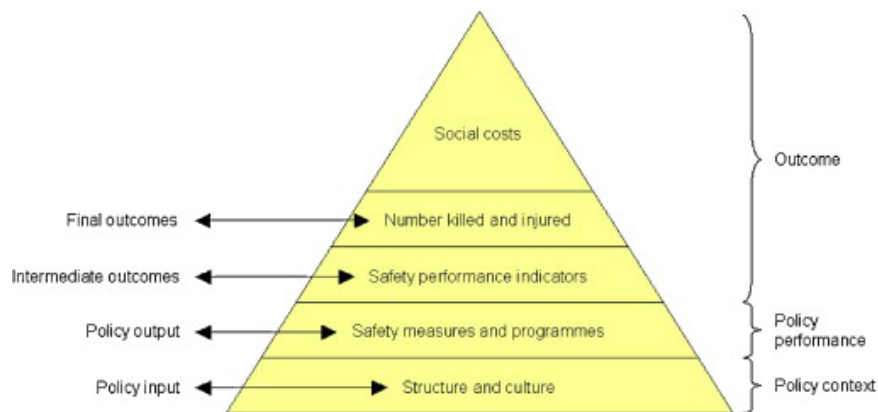


Figure 17: Road safety target pyramid (Koornstra et al., 2002; Papadimitriou & Yannis, 2013)

Their conclusion was that road safety management is often not linked to the ‘final outcomes’ layer, but is instead linked to the layer underneath, the ‘intermediate outcomes’. These intermediate outcomes are obtained by safety performance indicators, just as the studies in the literature review of this thesis focused on. The number of fixations and duration of these fixations are often measured, as well as lane deviation, headway distance and speed regulation. These driving capabilities are measured against change in task demand, i.e. the presence of billboards. These studied changes are varying from analyzing different sign content, different luminance, different dwell times and several more. When driving capabilities of drivers are impaired, this could potentially be harmful for drivers. This is the case when the demands of the driving task are greater than the capabilities of the driver (Oviedo-Trespalacios et al., 2019).

6.1.2.1. Literature findings

As already known in 2019, recent literature is consentient on a topic as video advertising; this is concluded to be too demanding for road users. It results in a widely-supported policy recommendation of prohibiting the use of video on digital billboards (Oviedo-Trespalacios et al., 2019; Wang et al., 2021; Brome et al., 2021; Felisberto & Casarin, 2024). This is a clear example, however, on lateral distance for example, clear policy recommendations by literature are more difficult. A study from Costa et al. (2019) on lateral distance, i.e. the offset of an advertising object to the roadway, mentions that the more clearance, the lower amount of fixations by drivers. However, a minimum, or optimal distance is not provided for policy recommendation, as this is difficult to assess. In Table 3 in section 3.3, an overview is provided of literature findings and their policy implications. The literature shows to be often conclusive on their findings and general recommendations. The policy implications however, so how to incorporate the literature findings into pragmatic policy guidelines, are more complex. Often it is not possible to provide hard numbers to assess a demanding road segment, exact times for appropriate dwell time or a concise checklist for assessing sexual content. This leaves policymakers with consistent and scientifically grounded recommendations, but at the same time with room for interpretation and responsibility for accordingly implementing recommendations into guidelines.

6.1.3. Discussion best practices comparison

In the previous section is discussed that scientific studies to safety performance indicators are often consistent and provide general, but scientifically grounded recommendations for policymakers. After this, it is up to policymakers to implement this into pragmatic policy guidelines. As this thesis aims to gain insight in how the Dutch assessment framework could be updated, there is looked other countries’ best practices. This way, insight in implementation of guidelines is generated.

The official information on guidance documents on roadside advertising is often stored on governmental webpages. These webpages are often difficult to search, especially when the native language of a country

is used. To cope with this, an AI tool was used to retrieve the official information from countries' webpages. Structurally questioning ChatGPT 5 was shown to be a suitable method to get a quick, concise overview on where to look for this official information.

6.1.3.1. Findings of best practices comparison

The official information of seven countries was reviewed thoroughly, to be Denmark, Finland, New Zealand, Norway, Switzerland and the United Kingdom. Just as in the comparative review of best practices by Boets et al. (2018), it was found that the countries showed quite significant variation between the level of detail of guidelines. Although it was clear to recognize the scientific foundation for guidelines for almost every reviewed country, only New Zealand explicitly mentioned their references. Norway and New Zealand both have extensive coverage of current knowledge, and thus their fundament of the guidance document. However, New Zealand did present it as a scientific robust literature review, whereas Norway did not mention any references.

In best practices of other countries, there were additional topics found in guidelines that the recent literature did not cover. Although most discussed topics are similar, some differences between the literature review of this thesis and the comparison analysis of this thesis are the coverage of message sequencing, the maintenance of advertising objects and the viewing angle of an advertisement along the road. It shows that during the drafting of guidelines a more pragmatic approach is used, a wide array of potential distracting factors needs to be covered, in order to mitigate potential safety impact.

An example of using different pragmatic approaches can be illustrated by the different guidelines regarding curved roads. As found in the literature review, there is scientific consensus on the demanding nature of tight curves, opting for a conservative approach (Costa et al., 2019; Sorum & Pal, 2022; Sheykhfard et al., 2024). However, countries cope differently with a recommendation like this. Denmark mentions a radius of 400 meters and less for distinguishing a tight curve. On the other hand, New Zealand uses the presence of chevron boards as indicator for a tight curve. The Netherlands current assessment framework refers to the Dutch design manual for roadways, where radiuses for tight curves are mentioned. Three countries with different guidelines on placement of roadside advertising nearby tight curves, but all three covering the same potential safety hazard.

Another example of different interpretation of a guideline, while having the same scientific evidence-base and even the same reasoning, is found for deciding on dwell times of digital billboards. While all reviewed countries acknowledge the distracting factor of changing images, the details in their guidelines on dwell time, differ for each of the countries. Norway prohibits the change of images on digital billboards, so no dwell time is used. Denmark uses 6 or 10 seconds, depending on the amount of digital billboards along a road. Finland uses 30 seconds, for every road. The dwell times of the Netherlands vary from 6 seconds, all the way to 12 hours. With the remark that 12 hours only apply for rush hour of certain busy roads. And since rush hour does not last 12 hours, it is stated that this particular dwell time should be read as 'no image change allowed' (Rijkswaterstaat, 2019). New Zealand, in their turn, start with a minimum of 10 seconds, and use a 'checklist table' for adding 10 seconds of dwell time per driving aggravating circumstance. See Figure 14. At the end of this checklist, it is stated that there should be checked against the principle that most road users are only able to see one image, and thus no changes (NZTA, 2025). This guiding principle of having road users to see maximum of one image change is also mentioned in the Danish and Dutch framework.

It underlines that policymakers from different countries use the same scientific principles for designing guidelines. The details of these guidelines, however, are completely different, as can be read in the paragraph above. It shows that there are multiple ways to implement the knowledge derived from scientific research. Deciding which 'best practice' is actually the best, is difficult, maybe impossible, as

current studies are not capable to assess the factual 'best' dwell time. This causes that there will always remain a longing for quantitative data-based evidence. Such as results crash data analysis.

6.1.4. Discussion crash data analysis

In the conducted before-and-after analysis, all crashes within the influence zones of the treatment sites were counted and compared with the comparison group. The same comparison group was applied to every treatment site. For one billboard no crashes were observed in the before period and was therefore excluded from further analysis.

Sixteen billboards were digitized from static to digital billboards and 4 were newly constructed digital billboards that did not exist in the before period. For each billboard, an estimated effect, corresponding weight, estimated safety effect, and associated 95% confidence limits were estimated. The number of crashes for the treatment sites were generally low, resulting in estimated safety effect that had large and widely varying confidence intervals.

More stable results were found when looking at aggregated effects using the Weighted Mean Effect. This resulted in a positive, statistically significant safety effect. This would imply that installing a new digital billboard or digitizing an existing static one is associated with a reduction in nearby crashes, which does not correspond with findings in (recent) literature.

6.1.4.1. Limitations

The main limitation is that there are small numbers on observed crashes used in the analysis. Small numbers are more prone to random fluctuation on year-to-year basis and often result in widely ranging confidence intervals. Another methodological implication could be the use of no site-specific control groups. This is often done to have a best possible comparison. However, in this study design, it was chosen to use the state road network of the Netherlands as a whole for comparing the treatment sites.

Another aspect is the context-specific setting. The Dutch context is that one of a well-performing, strongly regulated system (Wegman & Oppe, 2010). Although this does not directly explain the obtained positive safety effect, it could be a plausible reason that no negative impact is not showed by the data. Which would be expected based on existing literature on safety performance indicators. One explanation could therefore be that the Dutch safety system is found be rigid enough for potential safety impacts by roadside advertising. But the knowledge gap remains, in fact, we do not know to what extent digital billboards impact road safety.

6.2. Conclusion

The main research question of this thesis is:

What are the differences between current evidence-based insights and the Dutch policy framework about placement of roadside advertising objects along (high)ways?

When asking the question on what information is needed to improve guidelines and regulations regarding road safety, the often-mentioned answer is the need for scientific evidence. It does seem plausible and undeniable that scientific evidence is needed to strengthen policy guidelines and policymakers thus often long for this. The question, however, is what knowledge is currently available, and how this compares to current policy guidelines. Regarding roadside advertising, there is a significant amount of research conducted and presented over the years. Existing literature shows that the presence of roadside advertising does impair the capability of drivers, by increasing fixations away from the roadway, causing lane deviation and influencing headway distance. These safety performance indicators are well-studied via simulator studies, naturalistic driving studies and recognized in literature reviews. However, proving a causal link between roadside advertising and crash data is shown to be very difficult, if not impossible,

due to methodological limitations for crash data analysis on roadside advertising. Ideally, policymakers prefer to take an engineering approach and base their policy guidelines on indisputable evidence, but this is rarely achievable. Therefore, road safety management is more often linked to safety performance indicators, rather than final outcomes as fatality and injury rates.

When coping with scientific insights on safety performance indicators, policymakers are keen to take a pragmatic and straightforward approach, preferably using fixed numbers to limit the leeway for a guideline. Think of fixed dwell times for image change on digital billboards, maximum font sizes for text elements, or specific luminance output for illuminated advertising. This marks the characteristics of a 'best practice'. And there is nothing wrong with that, however, it does come with limitations. Without using such details in guidance documents, there is room for play, and thus discussion. With using this level of detail, there is room for questioning the exact scientific evidence for these specific numbers, and thus discussion. Is a 'best' practice ever good enough? That is difficult to answer, but there are enough resources to construct the best 'best practice' one can do. This thesis aimed to contribute to this, by providing an overview of these resources.

This thesis provided an overview of current state of scientific research, whereafter an overview of international guidance documents was presented. In addition, there was a crash data analysis conducted to contribute to the (lack of) quantitative research.

The literature of the past six years has been identified by a structural snowballing procedure, after which the articles were structurally reviewed. These recent findings were presented, and it can be concluded that on the majority of aspects of roadside advertising, literature is consistent and conclusive. The evidence-base for identifying potential safety aspect grows and as a result, policy recommendations are provided. Recent research is useful for road authorities to strengthen their scientific fundament of guidance documents.

The overview of international guidance documents provided by this thesis, showed that road authorities indeed use a scientific fundament to build their guidelines upon. Although often not explicitly mentioned, it was evident to see on which principles the guidelines were based. However, as a result of the pragmatic approach of policymakers, the level of detail varies between the guidelines of the analyzed countries. The objective of this thesis is to provide an overview of information that can be used to improve and revise the Dutch framework. The provided overview of best practices in other well-performing countries does show differences and new approaches, compared to the Dutch framework. For the objective of improving and revising the Dutch assessment framework, this overview can be used as helpful mean to learn and adopt from.

Yet, there is still a knowledge gap of lacking the ability to assess safety impact by the use of conclusive data. This thesis conducted a before-and-after analysis on crash data in the vicinity of digital billboards. However, it must be concluded that the results of this crash data analysis are difficult to draw conclusions from. Although, the aggregated results show statistical significance, the findings do show typical similarities with other inconclusive crash data studies. The results showed widely varying confidence intervals on an individual basis and the use of small numbers of crashes does make the analysis less robust. As influence zones of digital billboards are relatively small, confounding factors can have a strong effect on the crash data in that zone. It remains unknown to what extent digital billboards have an influence on road safety. The significant positive safety effect on the aggregated level must also be seen in the light of a strongly regulated Dutch road system. Do billboards have a positive effect on road safety? Or does the Dutch road system perform very well on road safety hazards? Vice versa, even if a significant negative safety effect was to be found, it would be hard to conclude and transform this finding, as the same methodological limitations would apply.

Although the question of safety impact remains unanswered, guidelines on roadside advertising can still be improved and developed by new insights. Also, without conclusive data on crash risk figures, it is nonetheless relevant to use the available, conclusive research on safety performance indicators and the overview over guidance documents of other countries. A 'best practice' should be based upon the best available information, mention the reasoning behind guidelines as well as using examples, as it is called a best practice for a reason.

6.3. Practical recommendations

For improvement of the current Dutch assessment framework, there will be practical recommendations provided in this section.

Lateral distance and elevation

The findings in recent literature are confirmative for what is already included in the Dutch assessment framework. From international best practices it was found as new insight that Denmark and Norway both use a maximized distance, rather than a minimized distance. Regarding the Dutch assessment framework, it is recommended to keep this criterion as it currently stands. Costa et al. (2019) could be used in chapter 3 of the Dutch framework to strengthen the evidence-base for this criterion.

Moving images

The findings in recent literature are confirmative for what is already included in the Dutch assessment framework. From international best practices the confirmation was found that moving images are also prohibited in other countries. Regarding the Dutch assessment framework, it is recommended to keep this criterion as it currently stands. Wang et al. (2021) and Brome et al. (2021) could be used in chapter 3 of the Dutch framework to strengthen the evidence base for this criterion.

Dwell time

Recent literature confirmed that shorter dwell times cause more glances, and longer dwell times are thus preferred. Existing literature opts for a dwell time of at least 10 seconds. A guiding principle is to display only one image per driver. The dwell time formula by Roberts (2013) could help in ensuring this principle. From international best practices it was found that every country uses different dwell times. Denmark (vaguely) and New Zealand (extensively) differentiate between driving aggravating circumstances. Just as the Netherlands. Besides, the Netherlands is, among the analyzed guidance documents, the only country to differentiate for rush hours. Furthermore, it was found that Norway completely prohibits the use of changing images.

For policy recommendation, there are three main points. First, when differentiating for rush hour, where it is assumed that speeds are lower, it is striking that for roadways with no further driving aggravating circumstances, the same dwell time of 6 seconds is still used. As speeds lower, a higher dwell time should be used for achieving the 'max 1 change' principle. Also using 5 minutes here, would be more consistent.

Secondly, where a dwell time of 12 hours is used, there could be just stated: 'no image change allowed'. This is currently mentioned in text, but not in the dwell time overview table itself, which is odd. At the same time, 'no image change allowed' does seem as a rigorous dwell time, as even in slow moving traffic, 5 minutes could be an appropriate value as well. Or at least, the jump from 5 minutes to 12 hours seems odd.

Third, based on literature as well as on guidelines of other countries, 6 seconds dwell time as minimum is low. Based on literature, it would therefore be recommended to use a minimum of 10 seconds. With the same reasoning, a dwell time of 5 minutes seems rather long. As explanation, it is currently stated that

95% of road users would not see a change, when a dwell time of 5 minutes is used. No example calculation is given here; it is recommended to include such calculation or explanation.

Light emission and luminance

During the literature review, it was found that displays with higher luminance, as well as large, illuminated surfaces, and high contrast with natural background increase glare and distraction, especially in low-light conditions (He et al., 2021; Jaskowski et al., 2025). When analyzing other international best practices on how they cope with light emission and luminance, it was found that the Dutch framework seems to be one of the best-in-class on this topic. Regarding the Dutch assessment framework, it is recommended to keep this criterion as it currently stands. He et al. (2021) and Jaskowski et al. (2025) could be used in chapter 3 of the Dutch framework to strengthen the evidence-base for this criterion.

Driving task aggravating locations

Intersections, curves, and complex traffic environments increase safety risk when ads are present (Sorum & Pal, 2022; Sheykhfard et al., 2024). After analysis of international guidelines, it was concluded that turbulence zones are greatly covered by Dutch framework, while limits of tight curves are better specified in other frameworks. This leaves two policy recommendations for this criterion: first, although the content is extensive, there are currently no references used in the Dutch framework for supporting this criterion. Sorum & Pal (2022) and Sheykhfard et al. (2024) could be used in chapter 3 of the Dutch framework to strengthen the evidence base for this criterion. Secondly, curve radiuses of Dutch road design manual (ROA) could be included in Dutch assessment framework. Just as done in Denmark.

Resemblance to traffic related information

There were no new insights found in recent literature on advertisements that look like traffic information are also prohibited in other countries. It is therefore recommended to keep this criterion as it currently stands.

Expectancy

Message sequencing has not been covered in recent literature, but it is mentioned in the guidance documents of other countries. Just like in the Dutch framework, message sequencing is prohibited in other countries as well. Just as call to actions as the presence of QR codes and website links. It is recommended to include a more extensive list of examples of call-to-actions in the Dutch framework. The following call-to-actions can be added:

- E-mail addresses
- Phone numbers
- QR codes
- Questions and riddles
- Website links

Emotionally loaded content

Recent literature found that sexual or emotionally loaded advertising content generates involuntary attention shifts and reduce performance (Walker & Trick, 2019; Sorum & Pal, 2022). When comparing the Dutch framework to international best practices, it was found that other countries also mention that emotionally loaded content should be prevented. Regarding the Dutch assessment framework, it is recommended to keep this criterion as it currently stands. Currently, there is no roadside advertisement related reference in the Dutch framework. Walker & Trick (2019) and Sorum & Pal (2022) could be used in chapter 3 of the Dutch framework to strengthen the evidence base for this criterion.

Viewing angle

Viewing angle has not been covered in recent literature, but it is mentioned in the guidance documents of other countries. Denmark and Norway use the same minimum and maximum viewing angle. It is recommended to keep this criterion as it currently stands.

Blocking view of the road

Recent studies acknowledge the importance of clear view of the roadway. Other countries do mention that roadside advertising must not obstruct any traffic related information. Vice versa, Denmark and Norway mention the importance for advertisements to be fully visible as well for at least 5 seconds. At 100 km/h, this would mean at least 140 meters. Regarding the Dutch assessment framework, it would be an option to adopt the criterion that an advertisement should be visible for at least 5 seconds from the Danish and Norwegian guidance documents. However, no strong recommendation is made for this criterion.

Blue light

Recent literature found that blue and blue-cyan illumination by roadside advertising increases reaction delay and causes more missed hazards on the road (He et al., 2021). Blue light has not been investigated in the guidance documents of other countries. Regarding the Dutch assessment framework, it is recommended to keep this criterion as it currently stands. Currently, there is no scientific reference in the Dutch framework. He et al. (2021) could be used in chapter 3 of the Dutch framework to strengthen the evidence base for this criterion.

Spatial quality and landscape integration

Scenic quality reduces stress and supports safer driving, while visual clutter contributes negatively to perceived scenic quality (Anciaes, 2023). From the analysis of international best practices, it was clear that this topic is not covered widely, only Denmark had a unique insight, stating that by law, advertising is prohibited in open countryside. In the Dutch framework, this criterion is currently not elaborated on in chapter 3. Anciaes (2023) could be used in chapter 3 of the Dutch framework to strengthen the evidence base for this criterion. Furthermore, it is recommended to keep this criterion as it currently stands.

Other remarks

An important insight by recent literature is that long texts (Harasimczuk et al., 2021), brand recognition (Mustapić et al., 2021), the size of the advertising sign (Mustapić et al., 2021; AlKheder et al., 2024) and the information density (Marciano, 2020; Meuleners et al., 2020) increase fixation duration and interpretation time. Short slogans and minimal use of text is recommended by these studies.

Some insights by international best practices are that a maximum of total words or elements is used in several other countries. The guidance on contrast and use of colors that are easy to interpretate, is substantiated by example images.

Furthermore, Finland does mention a maximum billboard poster or screen size of 50 m². Other countries only mention that advertisements must not be strikingly large, in order to prevent distraction from the object itself. Lastly, New Zealand and Finland mentioned that in case of a malfunction, a digital billboard should be turned off automatically.

The insights above result in the following policy recommendations on topics that are currently not covered in the Dutch assessment framework.

First, non-traffic related references are used for the criterion in Dutch framework that objects and information that is unexpected, requires a longer interpretation time of drivers (criterion 3c in Dutch framework). Harasimczuk et al. (2021), Marciano (2020), Meuleners et al. (2020) and Mustapić et al. (2021) could be used in chapter 3 of the Dutch framework to strengthen the evidence base for this criterion. It is recommended to use examples to illustrate desired and undesired sign content.

Second, although not strongly recommended, but a maximum size of an advertising display/object could be included into criterion 3c of the Dutch framework, which states that it should be immediately clear what an object represents.

Third, it is recommended to include how to cope with a malfunction of a (digital) billboard. It is recommended to automatically shut these off, until the malfunction has been fixed.

6.4. Recommendations for future research

For further research on driver distraction and roadside advertisements, there is still a knowledge gap on risk figures. The uncertainties and limitations on crash data analysis are difficult to cope with. However, future research could use only use newly placed digital billboards, as the change from static into digital billboards may be too little to derive conclusive evidence on risk figures from. When doing a more extensive before-and-after analysis, more and more suitable comparison sites should be identified to analyze treatment sites against.

Outside the scope of this thesis was the coverage of different jurisdictions across countries. Some official information is applied as law, where others only have an advisory role, as the Dutch framework. It is unclear if strict or more advisory regimes lead to better implications for roadside advertising placement and ultimately, better safety results.

Another aspect that received little attention in both recent literature as well as in guidance documents of other well-performing countries, is the spatial quality and landscape integration of roadside advertisements. Whether roadside advertisement is desirable or not for other reasons than safety aspects, is a question that is not for this thesis to be answered. However, it is a legitimate question and could be investigated in future research.

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Appendix A

Table 8: Included literature in literature review after snowballing procedure

Author(s)	Year	Journal	Citations	Type	Found via citing
Anciaes	2023	Transportation Reviews	17	Literature review	Beijer et al., 2004 + Crundall et al., 2006 + Belyusar et al., 2016 + Stavrinou et al., 2016 + Young et al., 2017 + Mollu et al., 2018
AlKheder	2024	Expert Systems with Applications	9	Naturalistic driving study	Crundall et al., 2006 + Belyusar et al., 2016 + Mollu et al., 2018
Alqudah et al.	2025	Procedia Computer Science	0	Self-report questionnaire	Beijer et al., 2004
Berger Haladova et al.	2024	ACM Symposium on Applied Perception 2024	2	Secondary eye-tracking data-analysis	Crundall et al., 2006 + Mollu et al., 2018
Brome et al.	2021	Transportation Research Part F: Traffic Psychology and Behaviour	15	Driving simulator study	Belyusar et al., 2016 + Mollu et al., 2018
Bucsahazy et al.	2025	International Conference on Vehicle Technology and Intelligent Transport Systems, VEHTS - Proceedings	1	Naturalistic driving study	Crundall et al., 2006
Cernekova et al.	2024	Conference paper	0	Secondary eye-tracking data-analysis	Beijer et al., 2004 + Crundall et al., 2006 + Mollu et al., 2018
Costa et al.	2019	Applied ergonomics	43	Naturalistic driving study	Beijer et al., 2004 + Crundall et al., 2006 + Belyusar et al., 2016
Felisberto & Casarin	2024	InfoDesign	0	Literature review	Molino et al., 2009 + Belyusar et al., 2016 + Stavrinou et al., 2016 + Mollu et al., 2018
Harasimczuk et al.	2021	Current Psychology	10	Naturalistic driver study + Attention Network Test	Crundall et al., 2006 + Belyusar et al., 2016

Hinton et al.	2022	Transportation Research Part F: Traffic Psychology and Behaviour	25	Literature review	Beijer et al., 2004 + Crundall et al., 2006 + Belyusar et al., 2016 + Young et al., 2017 + Mollu et al., 2018 + Gitelman et al., 2019
He et al.	2021	Building and Environment	18	Driving simulator study	Beijer et al., 2004 + Belyusar et al., 2016
Jaskowski et al.	2025	Measurement Journal of the International Measurement Confederation	0	Machine learning data-analysis	Stavrinos et al., 2016
Marciano	2020	Accident Analysis & Prevention	15	Driving simulator study	Stavrinos et al., 2016 + Vlakveld & Helman, 2018
Meuleners et al.	2020	Accident Analysis & Prevention	26	Driving simulator study	Iteration → cited by Brome et al., 2021 + Hinton et al., 2022 + Sorum & Pal, 2022 + Anciaes, 2023 + Cernekova et al., 2023 + Felisberto & Casarin, 2024, AlKheder, 2024 + Berger Haladova et al., 2024 + Sheykhfard et al., 2024 + Yang et al., 2024
Mustapić et al.	2021	Tehnicki Vjesnik	10	Driving simulator study	Crundall et al., 2006 + Stavrinos et al., 2016
Oviedo-Trespalacios et al.	2019	Transportation Research Part A: Policy and Practice	118	Literature review	Beijer et al., 2004 + Crundall et al., 2006 + Belyusar et al., 2016 + Stavrinos et al., 2016 + Young et al., 2017
Sharma & Chakraborty	2024	Engineering Applications of Artificial Intelligence	18	Literature review	Beijer et al., 2004 + Mollu et al., 2018
Sheykhfard et al.	2024	Transportation Research Part F: Traffic Psychology and Behaviour	2	Self-reported questionnaire + Driving simulator study	Beijer et al., 2004 + Belyusar et al., 2016 + Stavrinos et al., 2016 + Young et al., 2017 + Mollu et al., 2018 + Gitelman et al., 2019
Sorum & Pal	2022	Civil Engineering Journal (Iran)	20	Literature review	Beijer et al., 2004 + Crundall et al., 2006 + Belyusar et al., 2016 + Stavrinos et al., 2016 + Young et al., 2017 + Mollu et al., 2018 + Gitelman et al., 2019
Vrkljan et al.	2022	Sigurnost	0	Driving simulator study	Young et al., 2017

Walker & Trick	2019	Safety Science	17	Driving simulator study	Belyusar et al., 2016
Wang et al.	2021	Sensors	10	Driving simulator study	Beijer et al., 2004 + Crundall et al., 2006 + Stavrinou et al., 2016
Yang et al.	2024	Transportation Research Part F: Traffic Psychology and Behaviour	8	Driving simulator study	Crundall et al., 2006 + Stavrinou et al., 2016 + Mollu et al., 2018

Appendix B

Table 9: Extensive overview table of analyzed best practices

Country	Denmark	Norway	Switzerland	United Kingdom	Finland	France	New Zealand
Demand of road environment							
Intersections	Placement prohibited nearby major intersections (3 or more lanes for each direction)	Placement prohibited at intersections	Prohibited in immediate vicinity of junctions or exists	It should be considered that at junctions and roundabouts, advertisements are more likely to affect public safety. No strong point is taken.			NZTA recommends placement away from intersections and interchanges
Curved road	<p>Illuminated roadside advertising should not be placed at sharp curves, hill peaks or just before tunnels and bridges</p> <p>Should not be placed in curves with a radius smaller than 400m</p>	Not be placed at sharp curves or hill peaks. Also not just before or after tunnel openings	Should not be placed in tunnels or before and after tunnels		Not in tunnels or 200 before or after tunnels. Not on bridges or 50 before or after a bridge		Must be placed away from tight curves (curves where chevron boards are needed)
With regard to speed	Differentiated between 90+ km/h roads; 60-90 km/h roads and 60- km/h roads. The higher the speed limit, the stricter the placement guidelines.						<p>For roads with a speed limit of 80 and lower, the suitability will be assessed on a case-by-case basis.</p> <p>For 80 km/h and higher, the NZTA does not support approval for the placement of roadside advertising</p>
Blocking vision	<p>Advertisement must not obstruct the view of signals, traffic sign or markings</p> <p>Must be clear vision for at least 5 seconds for traffic signs</p> <p>A table is provided with minimum distance for different speed limits</p>	<p>Must not obstruct clear view, or traffic signs, signals, and road markings.</p> <p>Advertisement itself should be entirely visible atleast 10 times (at 50-60km/h) or 15 times (at 70-90km/h) the largest dimension of the advertisement (diagonal of the screen).</p> <p>E.g. 15 (for high speed road)*20m (diagonal of screen) = 300m visibility distance.</p>		<p>Advertisements which obstruct or impair sight-lines at corners, bends or at a junction, may cause danger to road users.</p> <p>Blocking traffic signs or signals could be dangerous.</p>	Are not allowed in places where it obstructs traffic signs or road marking or impairs their detection		Must be placed away from traffic sign, signals and information
Turbulence zone	Illuminated roadside advertising should not be placed on roads that have 4 or more entrances/exits per 500m				May not be placed less than 200 meters before first interchange sign (knooppunt aankondiging)		NZTA recommends placement away from turbulence zones (merges or diverges)
Clutter	In terms of clutter, illuminated advertising should not be placed nearby famous monuments, or other eye-catchers	<p>Limited amount of advertisements in field of view at once</p> <p>Not nearby other eye-catchers</p>	Not to be placed in the vicinity of traffic signs or signals		Not within 100 meters of any other roadside advertisement		A table with minimum spacing between digital billboards for different speeds
Placement							
Angle of viewing the billboard	Angled 90-120 degrees to road user direction. Exactly the same as KBOA but 60 instead of 120 (interpretation of angle)	Also between 60 and 90 degree					differs per speed limit: FOV per speed: 50 kmh -> 30° to 90° 75 kmh -> 42,5° to 90° 100 kmh -> 55° to 90°
Meters outside of the roadway	Within 20 degree angle of road user view. Still outside Obstacle free zone	Within 20 degree angle of road user view. Still outside Obstacle free zone		Advertisements which are not placed with sufficient clearance, both lateral and vertically, may cause danger (no further details on distances)	<p>On motor- and expressways, at least 50meters from the centre of the carriageway (carriageway closest to the side of the road, in case of multiple carriageways)</p> <p>May not be attached to a noise barrier, or in between the roadside and a noise barrier</p>		<p>Overhead placement is prohibited by NZTA</p> <p>Lateral distance: For regular advertising: at least 1,5 meter on 60km/h and slower; at least 3 meter for roads higher than 60km/h.</p>

Table 10: Extensive overview table of analyzed best practices (continued)

Country	Denmark	Norway	Switzerland	United Kingdom	Finland	France	New Zealand
Sign type	Materials and reflection should be considered Should be attached securely, so that it can handle strong winds	Must not use reflective materials such as mirrors, as it can cause glare Also the non-advertising part of object, should be of neutral colours: grey, black, brown etc. Should be attached securely, so that it can handle strong winds			No elements that can cause glare or reflective material	Not permitted if visible from motorway	Non-static billboards/displays, so video and animation, are prohibited to install in locations where they are visible from the state highway Materials must not be reflective
Illuminance							
Rural vs urban	Illuminated signs must be able to regulate brightness with relation to surroundings. No further details.	Where there is no street lighting, illuminated road advertising should not be placed (exemptions for on-premise signs)		Illuminated advertisements that can result in glare and/or dazzle, due to their size and/or brightness, may cause danger (no further details)	If the road is unlit, no illuminating advertisement is allowed		Luminance level should comply with New Zealand (and Australian) standard for Outdoor Light Regulation
Day vs night		Should not have a brightness level higher than surroundings While it's dark, illuminated roadside advertising should not be switched on or off			During dark, semi-illuminated advertisements should not exceed luminance of 300cd/m2 At dusk, luminance should not be more than 5 times ambient luminance And advertisement should adjust its brightness automatically Exploitant of	All digital advertising devices must be equipped with a dimming system to adapt the lighting to the ambient brightness. Illuminated advertising signs must be switched off between 1am and 6am (nighttime) in municipalities of 800.000 inhabitants and less	Should be equipped with an automatic dimming system based on ambient light sensor
crash modus	Mentioned, but still undecided how to act upon; exploiter should ensure that illuminated advertisements functions appropriately				Crash modus: Advertisement should be turned off when completely or partially out of order		Should be programmed to automatically shut down in case of a malfunction. Should also be possible to shut down manually

Table 11: Extensive overview table of analyzed best practices (continued)

Country	Denmark	Norway	Switzerland	United Kingdom	Finland	France	New Zealand
Sign content							
Color	Bright colours, High contrast between colours. Avoid large white areas	Good contrast between text and background.					no large parts using red, orange or green, so that confusion with traffic signals is minimised examples of good and bad contrast is provided for general roadside advertising in (NZTA, 2021)
Text	Not contain more than 8 words, images, symbols or numbers in total Font size should be simple and large enough to be easy to read	No more than 8 words, images, symbols, number combinations in total Fonts should be large enough and easy to read (examples provided) Table with tekst height is provided: e.g. 420mm font size for 180m reading distance No difficult words or number combinations. No e-mail, webpages, phonenumber etc.					Up to 10 elements are allowed on an advertisement display, where one word is one element; up to 8 elements may be words. Every line of text may maximum be 40 characters. Elements are <ul style="list-style-type: none"> • every word used • an email (is thus permitted) • a website (is thus permitted) • a phone number (is thus permitted) • a picture • a symbol • a logo • a terms and conditions disclaimer • any other individual element. Good, clear exmpales are attached Text heights are also extensively mentioned
Images	Easy to decode						no flashes, momevent scrolling or any form of animation. Also no audio allowed. No split screen
Video	Illuminated advertising should not be showing moving images			Moving elements may cause danger	No moving images or flashing		Illuminated advertising should not be showing moving images
Emotionally loaded content	The advertisement should not contain messages that give rise to strong emotions	No content that can fear people is allowed					Emotional impact of billboards should be considered
Level of expectancy	Whole illuminated advertisement should be visible, in order to read and understand the advertisement as quickly as possible. Only one unified message may be displayed at once. Should be independent, so no message sequencing! No Phone numbers or QR codes, mail addresses, questions, riddles, of websites Also no direct call to action, by using STOP logo or arrows, or TEXT TO... Advertisement should not show news	Entire advertisement should be visible No STOP, BRAKE, and other words like that. Prices of goods and services are also mentioned as potential call to action words. Independent complete message Should not contain ambiguous images or optical illusions/deceptions	Only announcements with a traffic education, accident prevention or traffic control character are also permitted; any indications of the sponsoring organization of the announcement may occupy no more than one tenth of the board area	successive individual images which do not display the whole message may cause danger			No sequencing, should be standalone messages; should not include a QR code, or other call to actions for for example phone use
Size	Must not be strikingly large, but no fixed size is given	Not strikingly large, so that the size itself may cause distraction. No further rules		Size can confuse road user due to being unexpected.	Maximum advertising size is 50m ²		max 16 m ²
Resemble to traffic information	Must be no possibility of confusion with signals or messages on traffic signs	Should not be potentially confused with traffic notice from road authorities	Advertisements should not contain signals or guiding elements	Advertisements that resemble traffic signs, may cause danger (specified by mentioning red circles, triangles, crosses. Also mentioning arrows as being resembling) Illuminated roadside advertising that can be confused to traffic lights due to their used colour may cause danger	Must not contain traffic signs or colour schemes that resemble to traffic information		Must not imitate any traffic sign, signal or information, nor instructions; No large parts red, orange or green

Table 12: Extensive overview table of analyzed best practices (continued)

Country	Denmark	Norway	Switzerland	United Kingdom	Finland	France	New Zealand
Dwell time	<p>Should be at least 6 seconds and at least 10 for roads with multiple advertisements</p> <p>Starting point is that road users sees no more than one advertisement per passing vehicle.</p>	<p>Advertising where the content and message change more often than once a day is prohibited along roads outside built-up areas.</p>		<p>Frequent changes of the display, may cause danger (no details mentioned)</p>	<p>Dwell time should be at least 30 seconds, for every changeable roadside advertisement</p>		<p>Assessing the right dwell is difficult and the New Zealand guidance highlights the inconclusive literature on exact dwell time, while at the same time highlighting that the literature concludes that transitions contribute to distraction</p> <p>10 seconds is chosen as minimum;</p> <p>After that, 10 seconds needs to be added for every driving aggravating circumstance listed:</p> <ul style="list-style-type: none"> turbulence zone; road segments with medium or high risk rating, as identified by NTZA; road curves with chevron signs; pedestrians/cyclists crossings; pedestrian or cyclist crashes in past 5 years; deaths or serious injuries in past 5 years; visible from a highway with AADT ≥ 10.000; speed limit ≥ 50km/h; non-compliance with spacing between billboards; <p>outside the field of view as described in 'Angle'; for a billboard display larger than 16m²;</p> <p>After all these things, there should be checked against the principle that most drivers should see only one image.</p>
Transition	<p>Transition may only take maximum 1 second without visual effects</p>				<p>The change of advertisement must not occur by flashing directly to the next advertisement or through a short dark state, but the previous advertisement must fade out slowly over a period of approximately two seconds and the next one must come on over a period of approximately two seconds. Alternatively, the change of the previous and next advertisement can be implemented by overlapping by sliding from top to bottom or from left to right over a period of approximately two seconds.</p>		<p>The luminance may not differ more than 30% between two images</p> <p>Transition should be max 0,5 seconds without special effect</p>
Landscape and spatial quality							
	<p>By Nature Protection Act: Roadside advertisement is prohibited in open countryside, except for very small on premise signs</p>					<p>Prohibited in lot of places like buildings with historical status, and in the vicinity of Regional Natural Parks</p>	<p>No details provided, NZTA 'seeks to minimise visual impacts' both on landscape as well as heritage and monumental areas</p>

Table 13: Extensive overview table of analyzed best practices (continued)

Country	Denmark	Norway	Switzerland	United Kingdom	Finland	France	New Zealand
General or new remarks							
	Illuminated roadside advertising signs are prohibited on roads which are known to be accident-prone and/or safety issues	Well-defined what roadside advertising is. Also stationary vehicles are covered. A trailer that is clearly intended to be visible for advertising purposes is also treated as advertising. Examples are given extensively	Starts, just like the Danish and Norwegian one, with clear explanations and distinction for what is defined as advertising (with examples) for all types of advertising		Again, maintenance is mentioned, just as in Danish and Norwegian guidance. This time more concrete. Where Denmark and Norway state that advertisements should be properly maintained, Finland states that placement is prohibited in places where year-round maintenance is not possible	France guidelines are foremost about the advertising signage within cities	Definition of a digital billboard is provided. Here: static = image change only; non-static = animation, video, motion
	Provides a whole assessment form	Not to place at known accident-prone points	Also, the legal basis for the handbook is provided: all articles and sections of applicable road acts are noted			Different approach, France uses number of inhabitants as benchmark. In agglomerations of less than 10,000 inhabitants digital advertising is not permitted	The New Zealand guidance starts with an extensive literature review on digital roadside advertising and driver distraction. It contains reviewed literature on self-regulation; crash data analysis; driving effects (lateral control, headway control, gaze behavior, response time, error increase, approach speed). There is also reflected on the research complexity of this topic.
		Owner of advertisement object should be contained on advertising	For locations visible from motorways and highways, only on-premise signs are allowed. Only ONE per direction of travel, and no website address, phone numbers are allowed. Only the company's address (logo) is allowed				On roads with speed limit higher than 50 km/h, the roads are governed by the NZTA, and digital signage won't be approved within the corridor (=beheersgebied) of these roads. On roads with a speed limit below 50 km/h, where the bylaw does not apply, the NZTA does not support applications for placement within the corridor of these roads.
		Complementing chapters about enforcement and how to cope with illegal placed advertisements Also on application and appealing process					Not on roads where cyclists and pedestrians cross Not on locations where deaths or serious injuries are recorded in the past five years
							Some assessment principles are noted apart from the technical details regarding placement and sign content. These are that case-by-case assessment should be done, as well as monitoring and evaluating a billboard after installation. Also specialists should be consulted.
							Provides a clear overview/summary at the end