Transportation Research Part A 179 (2024) 103920

Contents lists available at ScienceDirect

Transportation Research Part A

journal homepage: www.elsevier.com/locate/tra

Traffic safety versus accessibility: Investigating resistance against speed limit reductions

Ida Kristoffersson [a,*], Christine Große [a,b], Leif Olsson [a]

[a] *Mid Sweden University, Department of Communication, Quality Management, and Information Systems, 851 70 Sundsvall, Sweden*
[b] *Luleå University of Technology, Department of Computer Science, Electrical and Space Engineering, Luleå, Sweden*

ARTICLE INFO

Keywords:
Road speed limits
Accessibility
Regional development
Goal conflict
Transportation policy
Policy conflict

ABSTRACT

For traffic safety reasons, Sweden has lowered speed limits on major roads that lack directional separation of traffic. For some of these roads, regional authorities, municipalities, and other local stakeholders have sent appeals to the government opposing the implemented speed limit reductions. The appeals have mainly referred to negative effects on regional development and have suggested that the speed limit reductions be abandoned. This paper identifies the characteristics of roads where appeals against speed limit reductions have been filed and where local stakeholders claim that speed limit reductions are a threat to accessibility and regional development. The results of logistic regression modelling show that appeals are more likely for speed limit reductions on long road sections, on European roads, and in areas with a state university, and less likely in areas with high population density and areas defined as vulnerable by the Swedish Agency for Economic and Regional Growth. We investigated these policy conflicts using frame theory. In this paper, we identify two policy frames: speed limits for traffic safety and speed limits for regional development. These two policy frames are related to different views on how to best strive towards regional accessibility and safety goals in remote areas. The different views are likely not easily aligned by more information or facts since they concern deeper questions, such as what constitutes basic accessibility of good quality and how large risks are acceptable on the road network. This study thus uncovers not only a policy disagreement but a policy controversy in the Swedish context.

1. Introduction

1.1. Background

For some years, the Swedish Transport Administration (STA) has systematically adapted the speed limits on Swedish national roads to target safety requirements. The STA's guiding principle is that roads with a traffic flow above 2,000 vehicles per day (yearly average mean) and without separation of traffic in different directions should have a speed limit of 80 km/h or lower.[1] This principle pursues "Vision Zero", which states that no one should die or be seriously injured in traffic (Prop. 1996/97:137, 1997). From 2014 until 2025, approximately 1,200 km of national roads are being adjusted to a higher speed limit and approximately 4,250 km are being adjusted to

* Corresponding author.
E-mail address: ida.kristoffersson@miun.se (I. Kristoffersson).

[1] https://www.trafikverket.se/resa-och-trafik/trafiksakerhet/sakerhet-pa-vag/hastighetsgranser-pa-vag/anpassade-hastighetsgranser/.

https://doi.org/10.1016/j.tra.2023.103920
Received 30 January 2023; Received in revised form 5 October 2023; Accepted 23 November 2023
Available online 4 December 2023
0965-8564/

Nomenclature

A	Accessibility index
B	Estimated parameter
CBA	Cost Benefit Analysis
d	Population density
δ	Vulnerable municipality
E	Road is European road
k	Number of independent variables in model
l	Road length
L	Likelihood
LL	Log-likelihood
n	Observation
N	Important road for national and international traffic
p	Probability
q	Quotient traffic safety benefit / travel time cost
s	Traffic safety benefit
t	Travel time cost
u	University presence
U	Utility
V	Part of utility known to researcher
w	Road width
x	Independent explanatory variable
y	Dependent variable

a lower speed limit (STA, 2020b). The STA also implemented speed limit adjustments before 2014, for example, during a major revision in the years 2008–2009 (STA, 2012).

The STA reviewed the short-term effects of changing speed limits. The results show that traffic safety mainly increased on roads where the speed was lowered from 90 km/h to 80 km/h (STA, 2012). This is also the type of speed limit change that was made on the largest number of road kilometres in Sweden—approximately 9,800 km—during the years 2008–2009 (STA, 2012). The total number of traffic fatalities on these 9,800 km of roads with a lowered speed limit decreased by 22 fatalities per year in the short-term evaluation (STA, 2012). The Swedish National Road and Transport Research Institute assessed the long-term effects. Their assessment showed that the long-term effects of reducing speed limits from 90 km/h to 80 km/h were smaller than the short-term effects, with a decrease of 14 fatalities per year (Vadeby and Björketun, 2015; Vadeby and Forsman, 2018). There has been no significant decrease in the number of seriously injured people. Overall, these results indicate positive long-term traffic safety effects on a system level from the reduction of speed limits from 90 km/h to 80 km/h on roads without separation of traffic in different directions.

1.2. Definition of appeals to speed limit reductions

The STA is the body that decides the speed limits on state roads in Sweden. These decisions may be appealed by, for example, regional and municipal authorities and other local stakeholders, if such decision is likely to affect someone's situation 'in a not insignificant way' (Public administration law, 2017:900; 2017). In its role as higher authority, the Swedish government reviews those appeals. In this paper, we use the term *appeal* for a submission of a demand to the government to review an already implemented speed limit adjustment. An appeal can be granted or rejected by the government. A grant appeal returns the issue to the STA, which is compelled to perform a new examination, during which the speed limit is set to the initial level.

Starting in 2009, protests against speed limit reductions became more frequent in Sweden (STA, 2012). A couple of years later, municipalities and regions started to send appeals regarding implemented speed limit reductions. The common argument was that speed limit reductions on long road sections, in areas with relatively low accessibility before the speed limit reduction, would generate negative consequences for regional development, including people's living conditions and companies' economic development (Regeringsbeslut I2022/01284, 2022; STA, 2012). Fig. 1 shows the process of speed limit reductions and appeals.

Until 2019, no appeals regarding speed limit reductions were granted, but in 2020, the Swedish government granted seven appeals against speed limit reductions, and the speed limits for these roads were reset to 90 km/h (Regeringsbeslut I2020/03063, 2022). The STA has not yet implemented any of the speed limit reductions planned for 2021. At the time of writing (June 2023), it is still unclear which of these reductions, if any, the STA will realise and when they will implement any changes.

Against this background, the conflict between measures to enhance traffic safety and those to improve accessibility in remote areas gains importance for assessments of future development. There is a need to balance traffic safety goals and accessibility goals, which are both part of the Swedish national transport policy (SFS, 2010:185, 2010).

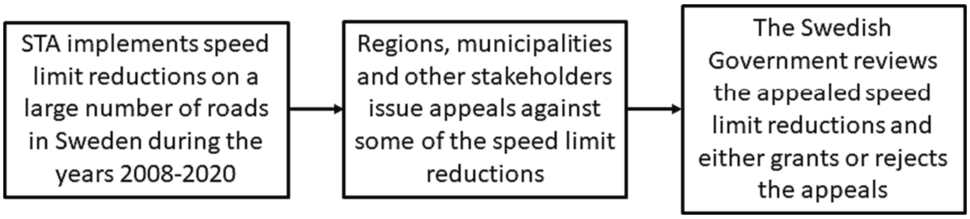

Fig. 1. The process of appeals in relation to speed limit reductions.

1.3. Research question and contribution

This paper investigates the factors that describe the road sections where local stakeholders have sent appeals to the government against implemented speed limit reductions, suggesting that they should be abandoned. The main research question of the paper is: What are the characteristics of roads where speed limit reductions are seen as a threat to accessibility for the region? The overall aim of the paper is to improve our understanding of the goal conflicts involved in accessibility and traffic safety. In particular, the focus of the study is on road speed limits as a means of improving road traffic safety and the goal conflicts this policy may evoke.

The contribution of this paper is twofold. First, we identify characteristics of road sections that are associated with increased resistance towards lowered road speed limits. Second, we discuss these findings in relation to frame theory and find the goal conflict to be a policy controversy that is not easily resolved by more facts; rather, it is related to basic questions about safety risks and what constitutes good quality accessibility.

After this introduction, Section 2 positions the study in theoretical and practical contexts and formulates hypotheses. Section 3 outlines the methodology, including data collection and analysis. Section 4 presents the result of the model estimation. Section 5 discusses the results, and Section 6 concludes the paper.

2. Theory

2.1. Swedish transport policy

Starting with problem identification, the generic policy process consists of five phases: agenda setting, policy formulation, decision-making, implementation, and evaluation (Jann and Wegrich, 2007; Rinfret et al., 2018). In Sweden, the public administration model is characterised by collective decision-making by the government, independent authorities, and strong local self-government at local and regional levels. The division of organisational responsibility between the government and the authorities is of particular interest (SOU, 1983:39, 1983; SOU, 2008:118, 2008). This relationship is described as dualistic or two-tiered since the responsibility for administration is shared between the government and the public agencies (Wennergren, 1998). This means that the government directs the authorities through directives, but the responsibility for interpreting laws and regulations and for the actual implementation of public policy lies with the authorities (Nergelius, 2012). The Swedish constitution states that governmental matters shall be collectively decided by the government at a government meeting. This statement establishes a prohibition of ministerial control of subordinate authorities (SFS, 2011:109, 2011). The Swedish administrative system, which prohibits ministerial rule, can thus be considered relatively unique from an international perspective.

The overall objective of Swedish transport policy is 'to ensure a socio-economically efficient and long-term sustainable transport supply for citizens and businesses throughout the country' (Prop. 1997/98:56, 1997). This main objective can be divided into two sub objectives, one targeting the function of the transport system and one considering safety, environment, and the public health effects of the transport system. The functional objective aims at developing the transport system so that its design, functioning, and utilisation 'should contribute to providing basic accessibility for all with good quality and usability and contribute to the development of the whole country' (Prop. 2008/09:93, 2009). In addition, the transport system should meet the transport needs of women and men. The objective regarding effects aims at avoiding death or serious injury, achieving environmental goals, and contributing to improved public health (Prop. 2008/09:93, 2009). The government states that both sub objectives are equal. However, the safety and environmental aspects have been concretised with specific goals, whereas the functional objective is not clarified, which allows for interpretation by the STA. The Swedish government introduced a particular goal conflict with a statement regarding the future development of the transportation system: 'To achieve the overall transport policy objective, the functional objective needs to be developed mainly within the scope of the objective considering safety, environment and health'.[2] This may be a major reason why the STA has prioritised safety-enhancing measures, especially road speed limit reductions due to their preferred cost-benefit relation (Swedish National Audit (Swedish National Audit Office, 2018, 2021). This approach to conducting policy implementation has led to public discussion (Große, 2022) of the equal pursuit of the two sub objectives and the STA's treatment of safety and accessibility concerns that result in appeals against speed limit reductions on Swedish roads.

As indicated above, Swedish authorities, such as the STA, are legally entrusted to implement measures within their area of

[2] https://www.regeringen.se/regeringens-politik/transporter-och-infrastruktur/mal-for-transporter-och-infrastruktur/.

responsibility. However, they are obliged to collaborate with other authorities and societal actors to fulfil their responsibility of investigating each matter 'to the extent required by its nature' (Public administration law, 2017:900, 2017). Swedish law requires authorities to inform any party concerned about all material relevant to a decision and to provide the opportunity to comment on that material within a specified period before taking a decision in a case. To meet these requirements, authorities regularly apply a referral process prior to making policy decisions. During such a process, authorities request opinions, called referrals, from concerned authorities, municipalities, and the wider public. In the case of the investigated road speed adjustments, the STA sent out *a priori* cost-benefit analyses of each speed limit reduction to inform the actors in the geographical area concerned and requested referrals. The STA answered the received referrals most often with standardised responses, for explaining the proposed decisions and giving negative replies to the arguments raised by regional and local actors. After such a referral process, the STA makes a decision or puts the matter on hold. When a decision is made, the authority must inform the concerned parties about the decision and, if applicable, inform them how and during what time period an appeal can be filed. Appeals can be sent regarding decisions by the Swedish authorities that are 'assumed to affect someone's situation in a not insignificant way' by the stakeholder(s) 'affected by the decision' (Public administration law, 2017:900; 2017).

2.2. Accessibility and regional development

There is an extensive body of literature discussing accessibility in relation to regional development. One of the seminal works is by (Koenig, 1980). He sees accessibility, or the ease with which opportunities can be reached, as a key concept in urban and transport planning. The relationship between transport infrastructure, accessibility, and regional development is, however, complex. Investments in transport infrastructure make travel and transport times shorter and increase the efficiency and competitiveness of an area, but they may, at the same time, increase differences in accessibility and economic opportunities between central and more peripheral regions (Vickerman et al., 1999). (Stelder, 2016) has constructed a historical road database for Europe and has calculated the change in road accessibility over time (1957–2012). According to his results, peripheral regions in Europe lost accessibility relative to central regions in Europe during the first part of the studied time period but have been catching up since 1990. Due to their complexity, accessibility benefits are difficult to measure, and many accessibility measures have been proposed over the years (Levine, 2020; Levine et al., 2019; Siddiq & D. Taylor, 2021). Accessibility benefits from transport investments emerge not only in the transport sector. They may also lead to increasing real-estate prices or increased wages, which are described as wider economic benefits (Börjesson et al., 2019; Graham and Gibbons, 2019; Knudsen et al., 2022).

Accessibility has a close relationship with population density since the concept is about the ease of reaching opportunities. There are more opportunities in areas with high population density. Accessibility can be increased either by decreasing the travel time needed to reach opportunities or by locating the opportunities closer to the traveller. (Levine et al., 2012) have analysed the impact of land-use and speed on accessibility and have found that speeds are slower but proximity between the start and end of trips is greater in metropolitan areas with higher population density.

Several studies have discussed accessibility in relation to vulnerability. We can take unemployment as a proxy for vulnerability. For example, research has found that vulnerable groups (with a high unemployment rate) in four cities in Europe (Barcelona, Madrid, London, and Rotterdam) have higher accessibility to public primary schools but lower accessibility to private primary schools (Romanillos and García-Palomares, 2018). (Norman et al., 2017) have shown that increasing accessibility to labour markets has a decreasing effect on the unemployment rate. This effect is more pronounced for workers with a lower level of education.

2.3. Traffic safety effects of speed limit changes

The relationship between speed limit changes and traffic safety has been subject to a long debate. Many studies have investigated the safety effects of increasing speed limits in the United States after the national maximum speed limit was relaxed in 1985 and removed in 1995, but the results of these studies are conflicting. Some studies found safety benefits of the increased speed limits (Lave, 1985; Lave and Elias, 1994; McCarthy, 1999); some indicated very small or no effects (Chang and Paniati, 1990; Pant et al., 1992); and some studies showed significant safety reductions (Baum et al., 1991; Ledolter and Chan, 1996; Wagenaar et al., 1990). (Kweon and Kockelman, 2005) addressed several modelling and data limitations in previous studies of the U.S. speed limit increase. Their results mainly point to the importance of road design for safety effects, such as wider road shoulders and more gradual curves. In the literature, there is also a discussion about trade-offs between speed and safety related to the so-called '85th percentile rule', which is a rule often used by jurisdictions in the United States to set speed limits at the speed of the 85th percentile driver (Taylor and Hong Hwang, 2020).

Two conditions must apply for a safety effect to occur following a speed limit reduction—the actual speed needs to decrease when the speed limit is reduced, and the reduced actual speed needs to lead to safer travel. (Wilmot and Khanal, 1999) conducted a review of studies investigating these two relationships and found that (1) drivers in general do not adhere to the speed limit, rather they choose speeds they perceive as acceptably safe, (2) what drivers perceive as acceptably safe is influenced by the road environment, the land-use next to the road, the geometry of the road, and weather conditions, (3) the effect of actual speed on safety differs depending on type of road, age of the driver, and the vehicle's safety equipment, (4) speed cannot be linked statistically to frequency of crashes but speed impacts severity of crashes, and (5) increasing speed limits can improve credibility with the public if speed limits are seen as unreasonably low. Contrary to Wilmot and Khanal, a study on speed limit reductions from 90 km/h to 70 km/h on many highways in Belgium found that *both* the frequency and severity of crashes decreased as speeds were lowered (De Pauw et al., 2014). A recent study on the effects of a general speed limit reduction in an urban setting from 30 mph to 25 mph in New York City found a significant reduction in fatal crashes (a 62 % decrease) but no effect on injury crashes (Zhai et al., 2022). Credibility with the public is discussed in (Peltola, 2000), who showed that acceptability for reducing speed limits on main roads in Finland from 100 km/h to 80 km/h only during wintertime is surprisingly high, which the author attributes to the understandable reason for the speed limit reduction.

2.4. Balancing of goals

Road speed limits are reduced as a means to improve road traffic safety, but at the same time, this implies a decline in travel quality as travel times increase. This is related to the two sub objectives of Swedish transport policy – one functional objective considering accessibility and one effects objective considering safety, environmental, and health aspects. On the one hand, the Swedish Government states that these two subobjectives are equal, but on the other hand the functional (accessibility) objective should be developed mainly within the scope of the safety, environmental, and health effects' objective. As described in section 2.1, this introduces a goal conflict between functional and effect perspectives.

In the mid-90s, (Haight, 1994) noted that most studies try to maximise either traffic safety or mobility. He called for more research that discusses the two topics together. Few studies have discussed both topics in a unified context or considered the goal conflicts that may arise. One exception is (Svensson et al., 2014) who have investigated setting speed limits on regional road networks in Sweden and the conflict that arises between safety and mobility. Svensson et al. have emphasised that there is a goal conflict in this area between actors representing the safety perspective and other actors representing the mobility perspective. Their results indicate that, at the regional level, actors representing the mobility perspective have more influence. Another exception is (Nitzsche and Tscharaktschiew, 2013) who have investigated the economic and social welfare effects of a general speed limit reduction in an urban setting. Their study shows negative urban economic effects of implementing a speed limit reduction to 30 km/h in the entire urban area, but more promising effects of a 'slow zone' in the city centre. (Westin et al., 2017) have discussed that in cost-benefit analyses, a speed limit reduction is more profitable for roads with a low traffic volume, and an investment in road safety features is more profitable for roads with a high traffic volume. From a longer perspective, changes in demand can lead to even further decreases in traffic volumes on roads subject to speed limit reductions. It then becomes even more difficult to justify any road investments, which results in a negative spiral for roads in sparsely populated areas.

In other policy areas, researchers have analysed policy conflicts using frame theory (Söderberg and Eckerberg, 2013). Frame theory tries to understand the different views people can have on the same situation or phenomenon. Policy conflicts can, according to frame theory, be divided into two categories—*policy disagreements* and *policy controversies*. Policy disagreements are related to a lack of information and can be resolved by the parties acquiring more information. Policy controversies are related to different ways of viewing facts and, therefore, cannot be resolved by simply adding more facts.

Applying a frame theory approach to the outlined Swedish context, we can characterise two policy frames: *speed limits for traffic safety* and *speed limits for regional development*. These two policy frames are supported by a division into safety and mobility perspectives when setting speed limits, which has been acknowledged by (Svensson et al., 2014). However, we use here the wording regional development rather than mobility.[3] In this article, the traffic safety perspective is the dominant perspective of the speed-limit setting body (STA) and the regional development perspective raises voices of disagreement. In (Svensson et al., 2014), the dominant perspective of the speed-limit setting body (the regional planning authority) was regional development and voices of disagreement came from the traffic safety perspective (citizens wanting lower speeds on urban roads).

By relating the identified policy frames to the existing policy goals for the Swedish transport system, we identified two conflict areas (see Table 1). The two policy frames exhibit similar views with respect to policy goals considering emissions and public health, which means that these goals do not engender policy conflicts. In contrast, different perspectives characterise the two frames' positions towards the policy goals regarding accessibility and traffic safety, which represent the policy conflicts in the Swedish context.

An important issue is thus whether these policy conflicts refer to policy disagreements or policy controversies. More facts about the question whether speed limit reduction is the most effective way to reduce the number of killed and seriously injured people in traffic may help to resolve the policy conflict; but more likely, the policy conflict boils down to different views on the risk levels road travellers should have to face and what basic accessibility of good quality actually is. Therefore, the present policy conflict appears to be a policy controversy.

2.5. Formulation of hypotheses

The aim of this paper is to identify characteristics of roads where speed limit reductions are seen as a threat to accessibility for the region. In this section, we formulate hypotheses regarding plausible characteristics based on the literature review and theory description above. The assumption is that regional and local bodies file appeals against lower speed limits since they fear that it will lead to longer travel times which in turn leads to accessibility levels not being considered good enough. Hypothesis H1-H4 below concern factors that are associated with negative impacts on regional accessibility.

Speed limit reductions on longer road sections will have a larger impact on accessibility and therefore we hypothesize that:

H1: A speed limit reduction on a long road section is more likely to generate an appeal.

[3] (STA, 2020b) write (p.49)*"Actors representing a mobility perspective have developed a strong policy discourse in decision and policy processes that centers around the idea that higher speeds and fast movement of goods and people is a fundamental condition for regional and local economic development and competitiveness"*.

Table 1
Existing policy goals for the transport system in relation to identified policy frames.

Policy goals (The transport system should…)	Identified policy frames: Speed limits for traffic safety	Speed limits for regional development
Provide basic accessibility of good quality throughout the country (Accessibility goal)	The guidelines for setting speed limits should be equal throughout the country	Some parts of the country risk not having basic accessibility of good quality
Be designed and used so that no one is killed or seriously injured (Traffic safety goal)	Reducing speed limits on roads without separation of traffic in different directions is the most effective way to reduce the number of people killed and seriously injured in traffic	There are other policy measures available that can reduce the number of people killed and seriously injured, such as investment in a centre rail or enforcing compliance with current speed limits
Contribute to reduction of climate emissions from domestic transport by 70 % from 2010 to 2030 (Climate goal)	Reduced speed limits have a small but positive impact on climate emission reduction	
Contribute to improved public health (Public health goal)	Reduced speed limits have a small but positive impact on air quality and thus on public health	

European roads are the backbone of the road system and therefore more important for accessibility, wherefore we hypothesise that:

H2: A speed limit reduction on a European road is more likely to generate an appeal.

As discussed in section 2.2, high-density areas have many opportunities within short distances. For low-density areas on the other hand, travel time is more important to reach the opportunities. We therefore hypothesize that:

H3: A speed limit reduction in a high-density population area is less likely to generate an appeal.

(Norman et al., 2017) showed that accessibility is important for vulnerable areas in order to decrease the unemployment rate. We therefore hypothesize that:

H4: A speed limit reduction in a vulnerable area is more likely to generate an appeal.

In addition to the above factors associated with negative impacts on regional accessibility, there are also capability factors, i.e., factors associated with the ability/time/resource of an actor to file an appeal.

Vulnerable municipalities are in general municipalities with a small population and limited resources. We therefore hypothesize that:

H5: A speed limit reduction in a vulnerable area is less likely to generate an appeal.

Education levels are in general higher in areas with a university. We therefore hypothesize that:

H6: A speed limit reduction in an area with a state university is more likely to generate an appeal.

Note that H4 and H5 cannot both be true at the same time. The results of the model will point to which of the two effects for vulnerable areas that are dominant.

3. Data and Method

This study identifies characteristics of Swedish road sections where speed limits have been reduced and for which local actors, such as municipalities, have submitted appeals to the Swedish government with the aim of reintroducing the original speed limit. A logistic regression model was used to investigate relationships between relevant characteristics and the submission of appeals. Logistic regression, also called logit modelling, is a standard method for transport science (Ben-Akiva and Lerman, 1985; McFadden and Zarembka, 1974; Train, 2003). It identifies the parameters of key variables related to the analysed choice situation while acknowledging that some variables are unknown to the modeller.

3.1. Data material

The data material consisted of 77 road sections in Sweden where the speed limit was reduced from 90 km/h (for a few road sections from 100 km/h) to 80 km/h in 2019 or 2020. Appeals were sent for 17 of these speed limit reductions, out of which 10 were sent for speed limit reductions implemented in 2019 and 7 for speed limit reductions implemented in 2020. For each data point, we have added information about road and municipality characteristics in the form of the variables described in Table 2. We took travel time and traffic safety effects from STA planning documents which constituted *a priori* anticipated effects. Measurements of effects after implementation of the speed limit reduction on the specific road sections were not carried out in this project. The data material was, therefore, not affected by the COVID-19 pandemic, which started in 2020.

The data collection included data material with observations of roads where speed limits should have been reduced in 2021 but were postponed. This data contained 10 observations and could be used to test the estimated model. Since we knew that one road section in the 2021 data set had been discussed before implementation more than others, it was interesting to investigate whether the model predicted an appeal for this road section.

3.1.1. Road section characteristics

The speed limit reductions considered were from 90 (100) km/h to 80 km/h on roads lacking directional separation of traffic.

Table 2
Available characteristics of the road sections in the material from 2019 to 2020.

Observations			Material I No appeal sent (60 obs)				Material II Appeal sent (17 obs)			
Variables	Unit	Notation	Mean	Min	Max	Stdv	Mean	Min	Max	Stdv
Road length	km	l	18.0	1.5	60.0	13.8	42.0	8.9	123.5	31.0
Anticipated travel time cost	kSEK	t	33,942	3,508	158,659	35,531	73,836	11,537	204,181	55,252
Anticipated traffic safety benefit	kSEK	s	50,482	4,653	317,753	57,553	105,699	16,652	258,591	80,584
Anticipated traffic safety benefit / anticipated travel time cost	%	q	145	107	213	25	143	108	179	18
Vulnerable municipality	0 = No 1 = Somewhat 2 = Medium 3 = High	V	1.2	0	3	1.2	0.2	0	1.5	0.4
Accessibility index	%	A	69	55	85	7	66	55	75	6
Municipality population density	Residents/km^2	d	43.5	1.1	287.0	48.5	23.0	0.9	61.5	19.5
Road width class	1 = <3.6 m 2 = 3.6–6.5 m 3 = 6.6–9.5 m 4 = 9.6–13.5 m 5 = >13.5 m	w	3.2	2.0	4.0	0.5	3.1	3.0	4.0	0.3
Dummy variables	**Unit**	**Notation**	**Yes** #obs	%	**No** #obs	%	**Yes** #obs	%	**No** #obs	%
Important road for national and international traffic	1/0	N	16	27	44	73	9	53	8	47
European road	1/0	E	6	10	54	90	6	35	11	65
University presence in municipality	1/0	u	9	15	51	85	5	29	12	71

There were differences between the roads, which could affect the probability of regional and municipal authorities submitting an appeal. These differences were related to width and type of road, where *road width class* (w) and dummies for whether the road section was a *European road* (E) or an *important road for national and international traffic* (N) were collected from open data in the Swedish National Road Database (NVDB).[4]

The considered road sections might also differ in the anticipated effects a speed limit reduction would have on travel time cost (t) and traffic safety benefit (s). These anticipated effects were estimated by the STA in a mandatory *a priori* cost-benefit analysis (CBA) of each speed limit reduction. Each CBA calculation was available on the STA's homepage.[5] A comprehensive data collection work within this study has been to compile these results into one common data set. The CBAs build on models for how traffic safety and travel time depend on speed limits. The effect on mean speeds from adjusted speed limits builds on measurements from previous implementations and template values are used for how much the mean speeds are likely to change. For example, a change in speed limit from 90 to 80 km/h is assumed to reduce the mean speed by 3.3 km/h for cars (STA., 2022). Changes in the number of crashes of different severity were assumed to only depend on the estimated change in mean speed, based on a relationship defined by the power model (Elvik, 2009). To exemplify, if the mean speed changes from 88 to 84.7 km/h due to a change in speed limit on a non-urban road, then the number of deaths is assumed to decrease by $1 - (84.7/88)^{4.6} = 16\%$. The valuation in monetary terms of the travel time increases and traffic safety benefits were based on national standard values described in ASEK (a Swedish acronym meaning *analysis method and cost-benefit values*) (STA., 2020a). Since the same simple model and standard valuations for effects of speed limit reduction were used for all road sections, the differences in CBA results depending on the road section were limited. The length of the road section (l) on which speed limit reductions were considered was also taken from the *a priori* CBAs.

3.1.2. Municipality characteristics

The variable vulnerable municipality (δ) was collected from a report published by the SAERG (2022). Based on data from 2018, the aim of the report is to describe municipalities' vulnerabilities to company closures. The report shows that vulnerable Swedish municipalities have, on average, fewer inhabitants than non-vulnerable municipalities. In the report, all 291 Swedish municipalities are put into one of four categories: 0 = not vulnerable, 1 = moderate vulnerability, 2 = medium vulnerability, and 3 = high vulnerability. As Fig. 2 depicts, this categorisation is based on a vulnerability index for each municipality. The vulnerability index derives from an additive calculation of several indicators that are normalised over the period of a year and weighted in the following way: 1/3 *company dependence* (number of companies needed to reach half of the total salary amount in the private industry); 1/6 *employment* (share of

[4] https://nvdb2012.trafikverket.se/SeTransportnatverket.
[5] Samhällsekonomiskt beslutsunderlag - Bransch (trafikverket.se).

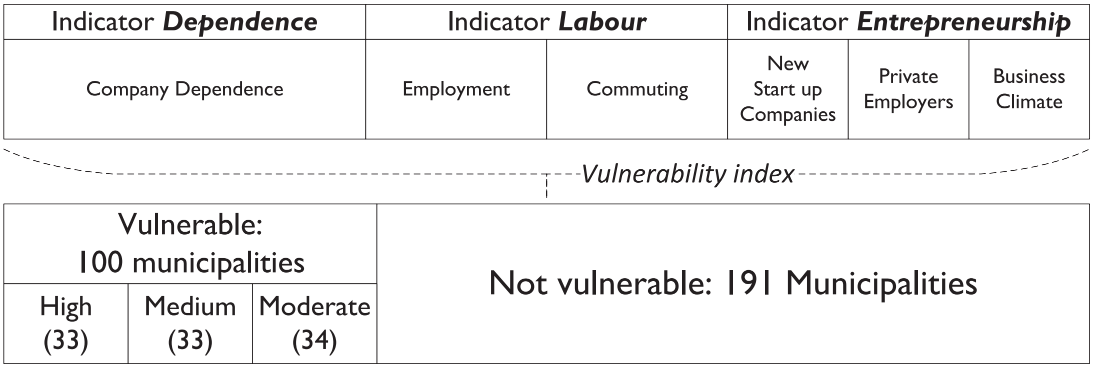

Fig. 2. Description of how the variable vulnerable municipality (δ) was calculated.

working population); 1/6 *commuting* (share of working population commuting to another municipality); 1/9 *start-up entrepreneurship* (number of newly started companies per 1,000 inhabitants); 1/9 *private employers* (number of private employers per 1,000 inhabitants); and 1/9 *business climate* (judgement of the business climate based on answers to a yearly survey sent out by the Confederation of Swedish Enterprise to around 70,000 companies in Sweden).[6] The 100 municipalities with the lowest index value were further divided into three portions, representing moderate, medium, and high vulnerability. If a road section passed through several municipalities, we calculated an average of the included municipalities, without consideration of how long part of the road section passed through each municipality.

Municipality population density (d) was based on Year 2022 data from Statistics Sweden.[7] As for the variable vulnerable municipality (δ), the municipality population density was calculated as an average of the municipalities alongside the road section without consideration of how long part of the road section passed through each municipality.[8]

The dummy for whether there was a state university in at least one of the municipalities the road section passed through (u) was collected from Wikipedia.

The municipality accessibility index (A) was collected from a report by Traffic Analysis (2021), a Swedish government agency for transport policy analysis. Transport Analysis calculates this municipality accessibility index in three steps. First, the share of population (in percent) that can reach each type of destination (grocery shop, pharmacy, postal service, fuel, health centre, elementary school, senior high school, airport, and railway station) with each mode (car, public transport, bicycle, and walking) within a travel time of less than 20 min in the road network is calculated. Second, the share is aggregated over all types of destinations for a given mode. Third, the accessibility share is aggregated over all modes. The result is the share of the municipality population that, on average, can reach all important types of destinations within 20 min using the modes car, public transport, bicycle, or walking. The variable was averaged over the municipalities the road section passed through without consideration of road length in each municipality.

3.2. Logistic regression model

We estimated a binary logistic regression model. The model investigated how characteristics of a road are associated with changes in the probability of an appeal being sent for the speed limit reduction on that road. The dependent variable y was binary (i.e., an appeal had been sent (1) or had not been sent (0)), and thus binary logistic regression was an appropriate method to use.

In binary logistic regression, the logistic function (Equation 1) is used to calculate the probability p_n of the event occurring (appeal being sent) for observation n and takes the form.

$$p_n(V_n) = \frac{e^{V_n}}{1 + e^{V_n}} \tag{1}$$

where V is the part of the utility, which is known to the researcher and is also known as the propensity score or log-odds.

$$V_n = \beta_0 + \beta_1 x_{1,n} + \cdots + \beta_k x_{k,n} \tag{2}$$

In Equation (X), $x_1, \cdots, x_k$ are independent explanatory variables and the β: s are parameters to be estimated, with β_0 being the alternative specific constant (ASC). We wanted to estimate parameters β, which maximised the likelihood of the events in the data material occurring. This was done using maximum likelihood estimation. The likelihood L of an event in the data material occurring was

[6] Foretagsklimat.se.
[7] https://www.statistikdatabasen.scb.se/pxweb/sv/ssd/START__BE__BE0101__BE0101C/BefArealTathetKon/table/tableViewLayout1/.
[8] Lista över universitet och högskolor i Sverige – Wikipedia.

$$L_n = p_n if y_n = 1 and L_n = (1 - p_n) if y_n = 0 \quad (3)$$

Due to potential numerical problems when multiplying a large number of small values, the likelihoods were logged (using the natural logarithm) and β: s were found that maximised the sum of all observed log-likelihoods.(LL_n)

$$\max_{\beta} \sum_n \mathrm{LL_n} = \max_{\beta} \sum_n \log\left[\mathrm{y_n} \frac{e^{V_n}}{1 + e^{V_n}} + (1 - y_n)\left(1 - \frac{e^{V_n}}{1 + e^{V_n}}\right) \right] \quad (4)$$

We tested and compared around 20 model specifications. To compare model specifications with a different number of parameters and to select the model that best fits the data, we looked at two metrics: Akaike information criterion (AIC) and the adjusted ρ^2. The model with the lowest AIC was the model that explains the greatest amount of variation using the fewest possible parameters. Equation 5 gives the AIC formula, and Equation 6 gives the adjusted ρ^2.

$$AIC = 2k - 2LL(\widehat{\beta}) \quad (5)$$

$$Adjusted\rho^2 = 1 - \frac{LL(\widehat{\beta}) - k}{LL(0)} \quad (6)$$

where k is the number of parameters in the model, $LL(\widehat{\beta})$ is the maximised value of the log-likelihood function, and $LL(0)$ is the log-likelihood when all parameters are zero.

The significance of parameter estimates was determined by testing if the estimated parameter was significantly different from zero. The cut-off value used was a t-ratio of 1.96 corresponding to a two-sided p-value of 0.05, or a 5 % risk that the parameter was not different from zero. We estimated the binary logistic regression models using the Apollo package in RStudio software.[9]

4. Results

4.1. Descriptive statistics

Descriptive statistics of the data are given in Table 2, where the data are separated into two categories—observations for which appeals were not sent (Material I) and observations for which appeals were sent (Material II). For these two materials, the mean, minimum, maximum, and standard deviations are shown. For both data materials, the *a priori* calculated traffic safety benefits are larger than the *a priori* calculated travel time costs for all observations. There are only small differences between the quotient of traffic safety benefits and travel time costs between Materials I and II. The differences between the two materials are small for the road width class.

For the other variables, there were several differences between Materials I and II. The length of the road sections for which appeals had been sent was considerably longer than the length of road sections for which no appeals were sent. The mean value was 42 km compared to 18 km. This affected the travel time cost and the traffic safety benefit, which both increased with increasing length. The mean value for the vulnerable municipality variable was lower (0.2) for observations where an appeal had been sent compared to observations where an appeal had not been sent (1.2). Regarding the accessibility index, the mean value was higher (69 %) for Material I compared to Material II (66 %). The mean value for population density was lower (23 residents/km^2) for observations where an appeal had been sent compared to observations where an appeal had not been sent (43.5 residents/ km^2). The share of roads important for national and international traffic was larger for observations where an appeal had been sent (53 %) compared to observations where an appeal had not been sent (27 %). This finding was also true for European roads, where the share was 35 % for Material II compared to 10 % for Material I. The share of road sections passing through a municipality with a state university was higher for observations where an appeal had been sent (29 %) compared to observations where an appeal had not been sent (15 %).

4.2. Result of logistic regression

This section presents the model estimation results. There are some variables that are not included in the final model since they were too closely correlated with the included variables. These are the *anticipated travel time cost* and *anticipated traffic safety benefit*, which were too correlated with road section length; the *accessibility index,* which was too correlated with *population density*; the *road width class;* and the dummy *important road for national and international traffic*.

The results of the model are presented in Table 3. The estimation results show that the propensity to send an appeal increased with the road length, with European roads, and with state university presence in at least one of the municipalities the road section passed through. The propensity to send an appeal decreased with the vulnerability level of the municipalities the road section passed through and with population density.

The significance level of dummy variables *European road* and *university presence* did not reach the 5 % significance level, but this could be due to a small number of observations (77), and we, therefore, kept these variables in the model.

[9] https://www.apollochoicemodelling.com.

Table 3
Parameter estimation results. Red values not statistically significant at 5% risk level.

Parameter name and notation	Parameter value	T-ratio
ASC (β_0)	−0.742	−0.69
Road length (l)	0.107	3.15
European road €	3.027	1.15
Vulnerable municipality (δ)	−3.434	−2.86
University presence (u)	3.053	1.78
Population density (d)	−0.082	−2.35
#Observations	77	
LL(final)	−14.82	
Adjusted ρ^2	0.61	
AIC	41.64	

4.3. Application of the model to Year 2021 road sections

In the data material, we had 10 road sections for which speed limit reductions were planned to be implemented in 2021. Speed limit reductions on these road sections had, however, been postponed. These sections can, thus, be used for an application of the model to evaluate which sections the model predicts where an appeal would be sent. The descriptive statistics of the 10 road sections are shown in Table 4.

Applying the model estimated in the previous section, the probability of an appeal being sent could be calculated for each of the 2021 road sections. The results are shown in Table 5. The most notable result was that the model predicted an appeal for the road section on E14 with a very high probability. This is the road section where the most protests emerged in the media. The model identified the most controversial road, which can be seen as a validity check for the estimated model.

Apart from E14, there was only one other road section for which an appeal was predicted with a probability higher than 0.5. The model gave a probability of 0.59 for an appeal concerning a 23-kilometre road section on Road 582. The reasons for this prediction were that the population density was quite low (16.3 residents/km^2) and that the municipality was not vulnerable.

5. Discussion

After speed limit reductions were implemented on many Swedish roads, local actors sent appeals against some reductions, but not against the majority. This study investigates which characteristics are linked to an appeal being sent. It demonstrates that increasing *road section length*, *European road presence*, and *university presence* increase the probability of an appeal being sent, whereas higher *population density* and *vulnerable municipalities* decrease this probability.

5.1. Variables related to road speed limit impacts

The result of this study confirms H1; that is, a speed limit reduction on a longer road section increases the probability of an appeal. The longer the road section with a reduced speed limit, the more extra travel time a traveller will experience, and the more accessibility will be reduced.

The result presented in this paper partly confirms H2; that is, a speed limit reduction on a European road seem to increase the probability of an appeal, but the parameter is only statistically significant at 30 % risk level, likely due to the small number of observations. European roads are the backbone of the road network in Sweden, and travellers therefore expect a high road standard and fast travel times on these roads. For European roads, many travellers and local and regional authorities expect and call for an investment in better road safety standards rather than lowered speed limits. The municipality of Ånge is an example of this stance (Municipality of Ånge, 2021).

Table 4
Descriptive statistics of the ten roads with postponed speed limit reductions.

Road number	Road length (km)	Vulnerable municipality (Scale 0–3)	European road (dummy 0/1)	University presence (dummy 0/1)	Population density (residents/ km^2)
9	18	0	0	0	69.7
E14	163.4	0.4	1	1	8.0
17	30.9	0	0	0	127.5
25a	4.5	3	0	0	13.5
25b	32.2	1	0	1	39.3
28	23.5	3	0	0	13.5
108	21	0	0	1	172.7
120	14.5	1	0	0	11.8
582	23	0	0	0	16.3
897	11.7	0	0	1	57.7

Table 5
Probability of an appeal for 2021 road sections calculated using the estimated model. Probabilities larger than 0.5 are marked in bold.

Road number	Probability
9	0.01
E14	**1.00**
17	0.00
25a	0.00
25b	0.29
28	0.00
108	0.00
120	0.03
582	**0.59**
897	0.24

H3 is confirmed; that is, speed limit reduction in a high-density population area decreases the probability of an appeal. There could be several reasons why a higher population density decreases the probability of an appeal. Municipalities with a high population density often have better public transportation services. Areas with low population density might, therefore, be more dependent on car travel and thus more resistant to a road speed limit reduction. In areas with low population density, the travel distances are also longer between people and services and opportunities, which implies a larger added travel time cost caused by the speed limit reduction. Accessibility in areas with high population density is to a large extent driven by proximity between the start and end of trips (Levine et al., 2012), and trips occur mainly on urban roads with low speed limits, which makes travel in high population density areas less affected by highway speed limit reductions. The result of this paper was that resistance against speed limit reductions is stronger in low population density areas. This finding concurs with previous research showing that low population density is one of the central factors explaining which states raised their speed limits on highways in the United States after the nationwide maximum speed limit was removed and states were allowed to determine their own speed limits (Albalate and Bel, 2012). Albalate and Bel have discussed how the valuation and trade-off between accessibility and traffic safety differ, depending on regional characteristics, with the valuation of time savings being higher in regions where long distances need to be covered to reach important travel attractions.

H4 is rejected by the model results of this paper. Being a vulnerable area *decreased* rather than increased the probability of an appeal.

5.2. Variables related to capability

The variables discussed above are related to the impacts of the speed limit reduction. Regional actors and municipalities that are more affected by road speed limit reductions are naturally more negative towards it. However, there are also factors related to capability. These are for example, characteristics of the actors submitting appeals, and their potential to voice disagreement.

The result of this paper confirms H5, i.e., that a speed limit reduction in a vulnerable area is less likely to generate an appeal. Since H5 is confirmed and H4 is rejected, it seems that for vulnerable areas the capability effect is dominant over the accessibility impact effect.

H6 is partly confirmed since the parameter is statistically significant at 10 % risk level. The results indicate that a speed limit reduction in an area with a state university is more likely to generate an appeal. A study on appealed community plans in southern Sweden also found that appeals were concentrated in areas within municipalities with high education levels among the population (Henecke and Olander, 2003).

The capability issue is related to the literature on responses to a quality decline, which (Hirschman, 1970) has identified as exit, voice, or loyalty. In our context, these three responses would translate into: stopping using the road (exit), showing discontent through appeals or media appearances (voice), and continuing using the road but starting the journey somewhat earlier to adjust for the longer travel time (loyalty). Sending an appeal is only one of the ways to respond and it is likely that vulnerable areas and areas without a university do not have the same resources to "voice" their disagreement compared to wealthier and more educated areas. Hirschman's three responses to a quality decline in the context of road speed limits in Sweden are also discussed in (Westin and Westin, 2022) from a commercial traffic point of view.

6. Conclusion

This paper aims to improve our understanding of the goal conflicts involved in the relations between accessibility and traffic safety. The focus is on Swedish road speed limits as a means to improve road traffic safety, on the one hand, and as a perceived threat to regional accessibility, on the other hand. The study analysed characteristics that have the power to explain the context in which road speed limit reductions are seen as a threat to accessibility for a region.

The following characteristics increase the probability of voicing disagreement with the speed limit reduction:

- Length of the road section where speed limits are reduced,

- European road,
- Presence of state university in the area.

The following characteristics decrease the probability of voicing disagreement with the speed limit reduction:

- High population density,
- Vulnerable municipality.

Regarding vulnerable municipality we tested two opposing hypotheses and results point to that the capability effect of less ability/resources for voicing disagreement is stronger than the impact effect of accessibility importance for a vulnerable area.

Furthermore, we identified two policy frames—*speed limits for traffic safety* and *speed limits for regional development*—and argue that the acts of the national speed limit setting body (STA) are dominated by the traffic safety policy frame, while the actors voicing disagreement through appeals are dominated by the regional development policy frame. These two policy frames likely exhibit different beliefs regarding the risk level road travellers should face and what conditions constitute basic accessibility of good quality. Thus, not only a policy disagreement but a policy controversy is present in the Swedish context. Future research should investigate pathways to resolve this policy controversy. Using a decision analysis model, future research could investigate how the different actors weigh criteria related to speed limit reduction and what the effects would be of changes in this weighting.

CRediT authorship contribution statement

Ida Kristoffersson: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Visualization, Writing – original draft. **Christine Große:** Conceptualization, Funding acquisition, Methodology, Project administration, Visualization, Writing – original draft. **Leif Olsson:** Conceptualization, Methodology, Validation, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

This research was conducted within the project "Förutsättningar för och lärdomar av hastighetsöversyn (Prerequisites for and lessons learnt from speed limit revision)" founded by the Swedish Transport Administration under Grant TRV 2021/52220.

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