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From trench war to dialogue: An action-research study of the assessment of barrier effects in a transport infrastructure project

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ABSTRACT

Transport infrastructure such as railways and motorways create barriers in local street networks, thereby reducing social contacts between people and limiting their access to shops and services. To address these barriers, a fact-based assessment of their effects is required. However, in current planning practice barrier effects are usually assessed through general descriptions and rough estimations. This paper presents an action research-based case study of what a newly developed set of barrier effect analyses contributed to the collaboration between the Swedish Transport Administration and the municipal council in a high-speed railway project. Interviews with participants (n = 22) showed that these analyses created a common language and offered concrete support, which increased trust between stakeholders and made it possible to reach a consensus about a planning alternative. Using the analyses entails interaction between practitioners and analysts throughout the work process, as the analyses and the impact assessments they provide support for are closely related. Among other findings, the importance of the street network emerged as the main variable in the analyses. There is a need to acknowledge this role and to create methods for adapting it to different planning alternatives of the infrastructure. Further, there is a need for more case studies on the collaborative processes of barrier effect assessments, as these are important for enabling the transition to more ecologically and socially sustainable transport systems.

1. Introduction

Transport infrastructure increases accessibility on a national and regional scale and contributes to economic growth. When assessing the impacts of investments in infrastructure it is important to consider that the benefits of increased accessibility can lead to regional inequalities in economic growth, as studied by Cascetta (2009). Another aspect, related to social sustainability, is how that infrastructure can lead to losses as well as gains through the barriers it creates for local traffic, predominantly for pedestrians and bicyclists. These barriers can lead to reduced social contacts and decreased access to services, shops, and leisure (van Eldijk et al., 2022). Active modes such as pedestrian and bicycle transport can become less attractive, which can have a detrimental impact on health (Higgsmith et al., 2022). It can also lead to an increase in car traffic and emissions, air pollution, and noise. As the rate of urbanisation in the world accelerates and cities continue to densify, the negative effects of infrastructural barriers increase.

Although tools for quantification of these effects do exist (Anciaes et al., 2016a), in current planning practice the assessment of the effects of barriers consists mostly of general descriptions and rough estimations. One of the reasons for their restricted use in practice is the limited dissemination of those tools (Anciaes et al., 2016b). A further challenge is that the complex, multi-faceted character of barrier effects requires collaboration between organisations and practitioners with different perspectives and responsibilities (Anciaes et al., 2016b; van Eldijk et al., 2022). Additionally, research on barrier effects is hindered by the fact that different scientific fields, such as traffic planning, public health, and urban planning, use different concepts and methods to study the problem (Anciaes et al., 2016b). In contrast, the assessments of other transport externalities such as traffic noise and air pollution, can be performed without the direct engagement of the involved organisations since these assessments are based on standardised methods and on regulations concerning maximum values.

The collaborative process of assessing barrier effects has not been studied before, and this paper contributes to filling this knowledge gap. In the paper, we present an action research-based case study of a new

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high-speed railway (HSR) through the town of Linköping in Sweden, in which a newly developed set of barrier effects analyses (BEA) were applied (van Eldijk et al., 2022). Through interviews with practitioners from the Swedish Transport Administration, their consultants, and the municipality of Linköping, we studied the contributions of the BEA to the project, and how the practitioners experienced the work process related to the BEA. The study aims to offer a deeper understanding of the processes of assessing barrier effects of transport infrastructure in practice. This understanding can create conditions for improved communication and collaboration between national and local authorities and other stakeholders. In a broader sense, this paper aims to contribute to improving ways to address social sustainability in the impact assessments of transport systems.

Following this introduction, we present the theoretical background of the study, with a description of the HSR project in Linköping and the research design of the study. We synthesise the results of the interviews in the discussion section. In the conclusion, we summarise the main findings, indicate the policy implications of the study and point out directions for further research.

2. Theory: Barrier effects, collaboration, and governance

In this section we introduce the main theoretical perspectives of the paper, starting with a description of what barrier effects are. Then we present a conceptual model of their determinants and describe some theoretical underpinnings of the process of assessing barrier effects, followed by key points from theories on inter-organisational collaboration and governance.

2.1. Barrier effects

Rather than being emitted from transport infrastructure, such as noise and air pollution, barrier effects arise in the meeting of several components (Korner, 1979). Transport infrastructure only becomes a barrier when it is in the way of someone on their way to somewhere. Fig. 1 presents the conceptual model by Van Eldijk et al. (2022) of the barrier effects of transport infrastructure and its traffic, that defines five determinants of barrier effects. *Transport features* can create physical barriers formed by the flow of traffic and fences as well as psychological barriers, such as fear of traffic accidents or fear of crime. *Crossing facilities and street network* define the physical conditions for movement across the barrier, such as numbers and locations of crossing facilities, height differences at crossings and the connectivity of the street network. *People's abilities* refers to mobility conditions of a person and the modes of transport that are available for them. *Land use* describes how the location and quality of origins and destinations determine when the need to cross arises. Lastly, *people's needs* determine which destinations people want to reach, and depends on aspects such as age and socio-economic characteristics.

The model (Fig. 1) distinguishes three levels of barrier effects (van Eldijk et al., 2022). *Direct effects* consist of the extra effort required for travel, such as detours, waiting time caused by the construction of new infrastructure, changes to existing infrastructure, and increased levels of traffic. *Indirect effects* occur when direct effects lead to changes in travel behaviour, such as choosing an alternative destination or mode of transport. *Wider effects* are the societal consequences of the indirect effects, for instance reduced social contacts, a decreased consumer or user base for commerce and services, and detrimental health impacts. The model also describes feedback loops that can occur when, for instance, high traffic flows force people to drive a car instead of walking or cycling to their destinations, which in turn adds to the existing traffic flow and increases barrier effects. The model gives names to the determinants of barrier effects and to the levels of these effects.

2.2. The process of assessment of barrier effects

Little research has been done on the process of assessing barrier effects. In their report on the social impacts of traffic barriers, based on interviews with officers at local authorities in England, James et al. (2005) describe that many participants found it difficult to describe the assessment of barrier effects in practice, "as there was little knowledge amongst most of the practitioners about the process" (James et al., 2005, p. 10). Moreover, participants were reported not to see barrier effects as a standalone issue but rather as intertwined with accessibility planning. In a comparative study, Enel (1998) noted an increased awareness of barrier effects amongst stakeholders in infrastructure projects and in general a more "urban approach to road planning" (ibid., p. 42). This increased awareness resulted in changes such as the area that is assessed

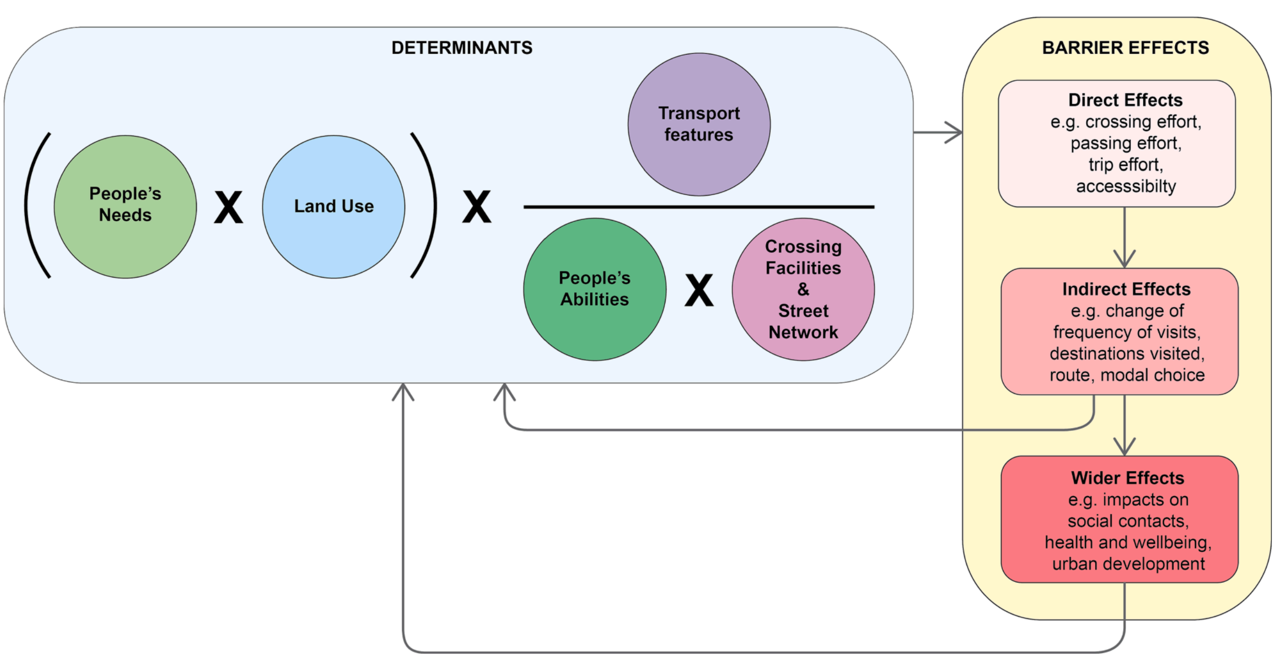

Fig. 1. Conceptual model of the barrier effects of transport infrastructure and traffic, describing the five determinants of these effects and the three effect levels that can be distinguished (van Eldijk et al., 2022)

being larger, that a longer period is considered, and that more parameters are included in assessments. The drivers behind these changes are: increased interaction between the state and municipalities, more attention to the pedestrian perspective, the development of methods for participation, and development of computer tools for visualisation. Despite these improvements, the interaction between the state and the affected municipalities was still experienced as a power struggle rather than collaboration (Enel, 1998). Participants described how information about the projects was withheld or shared too late, which reduced the collaboration to unilateral information about facts and decisions. Often there was no coordination between urban development projects and road planning. This appeared to be related to different perspectives on, and responsibilities for, the project: the transport administration is focused on the project until completion, the municipality from completion onwards.

The description of the hindrances to the collaboration between land use planners and transport planners by Te Brömmelstroet and Bertolini (2010) offers insights that are also relevant for the process of assessing barrier effects. These hindrances relate, amongst others, to the tools that are used by the respective disciplines, their operational modes ("holistic visioning versus optimising problem solving") and their professional language (Te Brömmelstroet & Bertolini, 2010, p. 86). Planning support systems (PSS) have been developed to accommodate this collaboration; however, they are not widely used in practice due to the difficulties in adapting them to the dynamic needs of planning practice, as well as insufficient transparency, flexibility, and user-friendliness. To overcome these hindrances, PSS and its output need to be developed in dialogue with the practitioners who use them.

2.3. Inter-organisational collaboration and governance

As stated above, barrier effects are multifactor phenomena that require collaboration between different organisations. Research on collaboration in planning practices highlights the importance of creating a collective understanding of the planning project in question, as well as common visions and goals (Huxham & Vangen 2005). Huxham and Vangen stress the complex nature of inter-organisational collaboration with a recommendation, put in simple terms: "Don't do it unless you have to" (2005, p. 80). Agreeing on aims and visions is a challenge, not only on a general level but also in detail, which can be difficult where there are clashing interests (Gil Solá et al., 2018; Pettersson & Hrelja, 2020). When the outcomes are predicted to exceed the effort of (successful) collaboration, there is a need to create an understanding of the different organisations' perspectives, guided by aims that can be connected to the collaboration and the organisations themselves. The aims can be both explicit and implicit, as well as hidden (Huxham & Vangen, 2005). As put by Paulsson et al., (2018, p. 378): "successful collaboration manages to develop and host both common shared goals and individual actors' objectives". Where a new collaboration is established, building trust between organisations is of prime importance, so that people are willing to share information and take risks. Moreover, it is important to reflect on pre-existing power relations and how they are likely to develop. Who is included in the collaboration, as well as how and by whom critical decisions are taken, are decisive questions (Huxham and Vangen, 2005).

One reason for the growing interest in collaboration is the ongoing shift toward planning based on governance, or the 'governance of place' as described by Healey (2003, p. 116). This process can be seen as part of the politicisation of planning (Schmitt & Wiechmann, 2018), where single-focus actors and responsibilities are replaced by networks of stakeholders striving towards common goals. Governance is often discussed in relation to participation of the private sector and civil society, but it can also apply to collaboration between actors within the public sector (Mäntysalo & Bäcklund, 2017). The transition to governance is in its essence an increased need for collaboration between different organisations. And since planning is a value-based practice (Grange, 2017; Healey, 2003), this collaboration is challenged by conflicts that can arise both inter- and intra-organisationally (Pettersson & Hrelja, 2020). The challenge here is to understand what roles different stakeholders occupy in the new networks of steering, and how power imbalances should be handled.

3. Case study: The East Link through Linköping

An opportunity to study the collaborative process regarding the assessment of barrier effects opened up when the company where the authors are employed was assigned to perform a route study of the high-speed railway East Link (Ostlänken) through the Swedish town of Linköping. Although this scale of railway projects is not representative for transport planning practice as a whole, the project was still deemed to be relevant as it offered a unique possibility to study collaboration processes in a large-scale infrastructure project that involves extensive barrier effects in an urban environment.

The East Link is a national project that will increase connections between the three largest cities in Sweden: Stockholm, Malmö and Gothenburg, passing several cities along its way. The Swedish Transport Administration (STA) is responsible for the railway, and the main aim is to reduce the travel time between Stockholm and Gothenburg from around three hours to two (Banverket, 2009). The project is estimated to be finished in 2035, and the process of defining a suitable location has been ongoing for several decades. One of the cities the railway will pass through is Linköping, the site of this study. Whereas the assignment of the STA is to build the railway at the lowest possible cost, what is important to the Municipality of Linköping (ML) is that the railway creates as few barriers as possible and that the station will be in a central location (Norrköpings kommun and Linköpings kommun, 2010; Linköpings kommun, 2016).

In the first route study, out of four locations the STA elected a corridor east of the Stångå river on elevated tracks and platforms for further analysis (Banverket, 2009). The station was planned for the east bank of the river Stångå, corresponding with the municipal plans. On this location, the ML wished to place the railway underground (Linköpings kommun, 2016). In response, in a complementary investigation by the STA, tunnel alternatives were included. Even though some positive aspects of an underground railway were shown, there were negative implications in terms of environmental effects and uncertain construction costs (Trafikverket, 2014). The tunnel alternative was therefore ruled out by the STA, despite it being seen as more or less essential by the ML (Hermelin & Gustafsson, 2021). In this conflict, the STA occupied a powerful position, with a mandate from the national government allowing them to decide to either locate the station outside of the city centre, or to not construct a station in Linköping at all. However, as Swedish legislation prohibits the construction of transport infrastructure in conflict with municipal land use plans, the STA was at the same time dependent on the approval of the ML for adopting the railway plan.

After a few years of unsuccessfully attempting to reach an agreement, in 2019 the STA initiated a new route study, involving a work process in which a strong focus was placed on enabling collaboration (see Fig. 2).

The project started with a series of workshops and meetings, involving the ML, the STA and their consultants, where 19 common goals were formulated for the project, split into four themes: (1) Function and economy, (2) Environment and health, (3) People and society and (4) Mobility and accessibility. In the next stage, the goals were translated into indicators and methods of measuring these. Thirdly, broad corridors were defined wherein the railway and station could be located (see Fig. 3). The consequences of each corridor in relation to the indicators were assessed in the fourth stage. Lastly, the assessments were summarised in a multi-criteria analysis to give an overview of how each corridor complied with the common goals defined in phase 1. The process concluded in a public hearing of the railway project, which

Fig. 2. The work process in the route study of the East Link through Linköping (Trafikverket, 2022a).

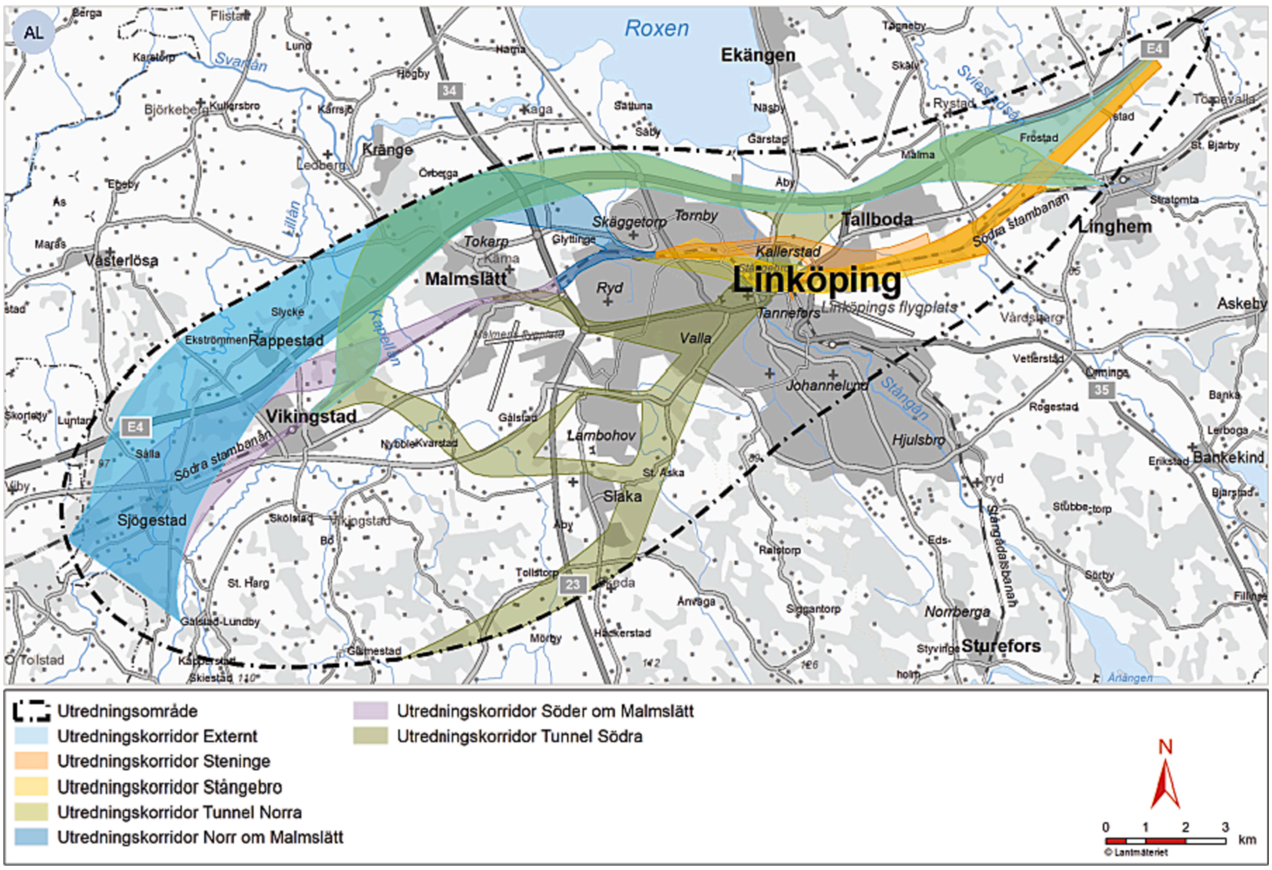

Fig. 3. An overview of the corridors for the East Link through Linköping (Trafikverket, 2022c).

constitutes a base for choosing one of the corridors (Trafikverket, 2022c). In the next stage of the project, the chosen corridor would be elaborated further in a railway plan.

During the route study, the Steninge corridor (orange in Fig. 3) emerged as an alternative possibility to tackle barrier effects other than constructing a tunnel. Even though it was a compromise – for the STA as it involves a slight detour for the railway, and more expensive than placing the railway in the outskirts of Linköping, and for the ML as it does not involve a tunnel – the two parties managed to reach a consensus about this alternative. On the 17th of May 2022, Steninge was formally chosen as the corridor to go forward with in the railway plan (Sadeghi, 2022).

3.1. Barrier effect analyses

In several of the common goals and indicators identified by the STA and the ML, barrier effects were considered to be of central importance. Therefore, barrier effect analyses (BEA) were done using indicators defined by van Eldijk et al. (2022). The quantitative measurements of barrier effects were used in five of the impact assessments: Traffic Impact Assessment (Trafikverket, 2022b), Architectural Program (Trafikverket, 2022d), Child Impact Assessment (Trafikverket, 2021a), Segregation/Social Impact Assessment (Trafikverket, 2021b) and Recreation Impact Assessment (Trafikverket, 2022a). The barrier effects introduced by the railway, as well as possible reductions of these barrier effects, were assessed through GIS-analyses (a reduction occurs in those corridors where the existing railway is combined with the HSR in a

Table 1
Analyses used for the barrier effect analyses (Trafikverket, 2021c).

Analysis	Description
Attraction Distance	Calculates the shortest distance from each segment to the closest origin or destination within a set. Distance is measured in metres through the network.
Attraction Reach	Summarises the number of origins or destinations it is possible to reach from each segment within a radius. Distance is measured in metres through the network.
Angular Integration	Calculates closeness through the shortest path, from each segment to every other segment within a radius. Distance is based on accumulated angular turns.
Angular Choice	Calculates the number of times a segment is part of the shortest path between segments within a radius. Distance is based on accumulated angular turns.
Isochrones	Analysis of a service area. Distance is measured in metres through the network.
Average Detour Factor	Calculates the relation between the Euclidean distance and the relative distance through the network.

tunnel). Place Syntax Tool (a plug-in for QGIS) was the main tool used. Table 1 presents a summary of the BEA. In addition to the quantitative analyses, qualitative BEA were made through design sketches and 3D-visualisations of the railway and the station. For more detailed definitions and examples of the analyses, design sketches and 3D-visualisations, see the Accessibility Impact Assessment (Trafikverket, 2021c) and the Architectural Program (Trafikverket, 2022d).

4. Research design

A methodological touchstone for this study is how knowledge is co-created, involving both academics and practitioners (Straatemeier et al., 2010). More specifically, following Dewey's observation that practical knowledge can only be generated within actual experience (Straatemeier et al., 2010), the focus was on the personal experiences of practitioners in the studied transport infrastructure project. Using these starting points, we have chosen the following research methods.

4.1. Action research

The study method for this paper was 'action research' (Herr & Anderson, 2015), meaning that the researchers are insiders and play an active role in the practice that they are researching. Since that practice is strongly influenced by its context, a case study approach was considered suitable (Yin, 2018) to create a broad understanding of the processes (Flyvbjerg, 2004). Both action research and the case study approach offer opportunities for deepened insights in the study object, as well as limitations regarding possibilities for generalising the findings (Hammersley, 2012). However, the knowledge produced in an action research project can be transferable through offering documentation of a successful collaboration and its product. Another challenge with action research is the risk of self-promotion by the researcher (Herr & Anderson, 2015). To deal with these aspects, the research team for this paper comprised one person who was responsible for the BEA that are studied, and one person who was involved in the project but not the development of the BEA.

The authors wish to declare that the STA partly financed the development of the methods used for the BEA and the study presented here. This background, combined with the facts that the analyses were done as an assignment by the STA and that the authors are employees at a consultancy, defined the approach to the project. The assumption was that the objective for the knowledge created is to contribute to the reaching of a consensus in conflicts related to transport infrastructure. This aim can be contrasted with the more critical approach where the objective of knowledge is to clarify how conflicts about investments in transport infrastructure result from wider conflicts related to the distribution of resources in society, conflicts for which there is no given amelioration (King, 1982).

4.2. Interview method and thematic analysis

The study is based on a series of semi-structured interviews conducted by one of the authors. To capture a variety of perspectives on barrier effects, different groups of people were interviewed: officers from the ML, from the STA and from the consultancies appointed by the STA. Of the 24 individuals who were involved with different types of impact assessments in which barrier effects played a role, 22 persons were willing to participate. They were asked to describe the work processes with the BEA, and what they thought of the contribution of the BEA to the five impact assessments. A guide was used for the interviews (see Appendix A), which was tested in a pilot interview and revised thereafter (Mason, 2002) and adjusted further after the first few interviews. The participants were given pseudonyms as follows: officers from the Municipality of Linköping: ML1 to ML7; officers from the Swedish Transport Authority: ST1 to ST4; the officer from the regional authority: RE1, and the consultants: CO1 to CO10.

The interviews were conducted via video call. They were between one and two hours long and were transcribed using an online automated service and thereafter corrected by one of the authors. The interviews were conducted in Swedish; quotes were translated only when they were added to this article. The resulting transcriptions were read and analysed by both authors using a coding program (NVivo). As the aim of the study is to develop existing theory about and methods for the analysis of barrier effects, we performed a thematic analysis of the transcriptions, adhering to the 15 criteria defined by Braun and Clarke (2006). In the analysis, we used descriptive codes (ibid.) in the 1st round of coding, and an elaborative coding technique in the 2nd round of coding (Saldaña, 2016). To ensure inter-coder reliability, the results of each round of coding were compared and discussed, as recommended by Thomas and Harden (2008), and codes and code descriptions were refined. In Appendix B we present the list of themes and codes that we have used in the analysis. In the 2nd round, we looked at the participants' descriptions through the lens of the barrier effects model in which five determinants of barrier effects are defined (see section 2.1). Indirectly, this is also a way of verifying the relevance of the model. In addition to the BEA, the accessibility of the proposed railway station was analysed in the different corridors (see PM Tillgänglighet (Trafikverket, 2021c) for a description of these analyses). These analyses are closely related to the BEA and were created by the same team, therefore both types of analyses were discussed by the interviewees. However, in the coding of the transcriptions, we excluded all comments and descriptions that were related to the accessibility of the railway station.

5. Results

In this section, we describe the participants' experiences of the contributions of the BEA and the role of the BEA in how the STA and the ML were able to reach a consensus regarding the preferred corridor in the project, followed by their reactions and reflections on the work process with the BEA.

5.1. Contributions

The reaction of nearly all the participants was that the BEA offered "concrete", "objective", "neutral" and "factual" descriptions of barrier effects, which was experienced and appreciated as an alternative to the many personal opinions on the project. As ML2 expressed it:

> The analyses give us support when we go through the goals and argue for a certain thing. (…) We know how they are made, and we can have them as proof that this is not just something we invented.

The BEA were perceived as impartial and trustworthy by both the ML and the STA. ML5 described how she/he/they experienced that the work process with the BEA was guided by the content of the project and not by the results that the STA wanted, adding that "it feels like it would probably have turned out the same if it had been the municipality that was the client." Moreover, the BEA contributed to a more equal collaboration between the STA and the ML, as they offered an "evidence advantage" (CO5) for aspects other than those areas that are solely the responsibility of the STA, such as regional and national accessibility and construction costs that are commonly supported with exact figures. Fig. 4 presents an example of one of the results of the BEA which were used for the traffic impact assessment. The BEA created support that was perceived to be trustworthy, as it was seen as based on descriptions of the impacts that the stakeholders agreed upon, and that was relevant to their interests and areas of responsibilities. ST3 portrayed the BEA as "a way of meeting", and many officers from the ML experienced the analyses as coming from an independent, third party. As stated by ML2:

> …to get the material from outside as an independent party […] felt good. And I think it was also valuable that the material had been

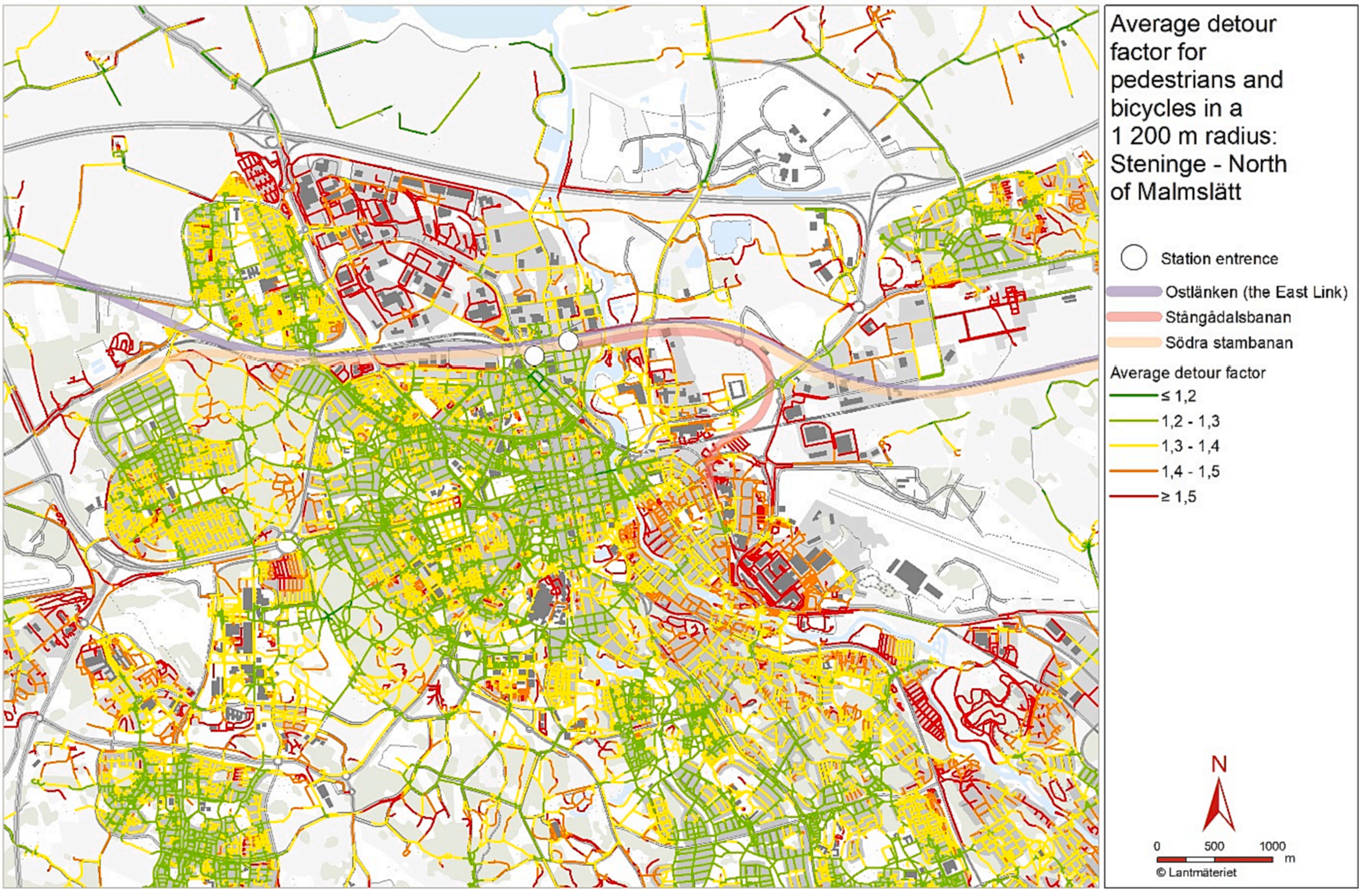

Fig. 4. Example of the results of one of the BEA: Analysis of the Steninge corridor for the average detour factor for cycle and pedestrian trips within a radius of 1 200 m from each street segment. Range detour factors between $\leq$ 1,2 and $\geq$ 1,5 (Trafikverket, 2022b).

> presented to both the ML and the STA at the same time so that we heard the first reactions and could reflect on the material together.

Despite initial scepticism, ST2 described how, in retrospect, the BEA also offered benefits to the STA because they created a situation where the STA was able to meet any objections from the ML regarding, for instance, impacts on urban development. As ST2 put it: "This time we went in with, well… all bases covered".

5.2. Assessing the Steninge corridor

One specific example of the contributions of the BEA is its role in the attainment of consensus about Steninge as the preferred corridor. As described in section 3.1, the STA and the ML had very different perspectives on the project, which were succinctly summarised by RE1: "There is still a discussion: is this an urban development project or is it a transport project?" In the initial phase of the route study, the prospect of finding a compromise between the interests of the STA and the ML had become less likely. On the one hand, the costs of the tunnel corridors were estimated to be even higher than expected, making them less acceptable for the STA, while on the other, the BEA showed that the railway and the station on the ground-level version of the Stångebro corridors (see Fig. 5) would create even greater barrier effects in the city than had been assumed, thus thwarting ambitions to reduce barrier effects and to expand the city in this area. As ML2 reflected:

> We started to analyse the urban development opportunities [east of the city centre], where we considered the facts that one first needs to cross [the river] and then go under [the existing railway], and then under the East Link. We now realise even more that this is not good for urban development opportunities (…). Is it even possible to develop this area and feel that it is part of the inner city? Will people even want to go there?

At this time, the BEA started to show the potential of the Steninge corridor (see Fig. 6). Steninge had been developed by CO5 and her colleagues, but had been met with strong scepticism on both sides. However, the BEA showed the politicians and ML officers that Steninge complied better with the municipal urban planning goals than the Stångebro corridor:

> I think that the urban development scenarios and the analyses have also helped to show that [Steninge] corresponds quite well in several respects with the intentions [for urban development] that the municipality has adopted. Even though we had Stångebro as the preferred location for the station (…) we now see that it is possible to [develop the centre] in the Steninge corridor as well, or maybe even more so. (LM3).

When other assessments also pointed out the benefits of Steninge, the STA also became convinced about this corridor. In March 2022, the ML issued a formal statement on the route study, stating that even though the municipality still favoured a tunnel corridor, Steninge was now the preferred ground-level corridor. "This corridor", they wrote, "moves barrier effects connected to the existing railway facility away from the city centre while simultaneously a central station location can be achieved." (Linköpings, 2022). According to CO9, the BEA played a crucial role in this decision:

> There are a number of analyses that I think have actually opened our eyes, both internally, at the ML, as well as at the STA. I think if we had not done all these analyses, if we had not had all these meetings, *all these meetings,* then it would have been so easy to decide in favour

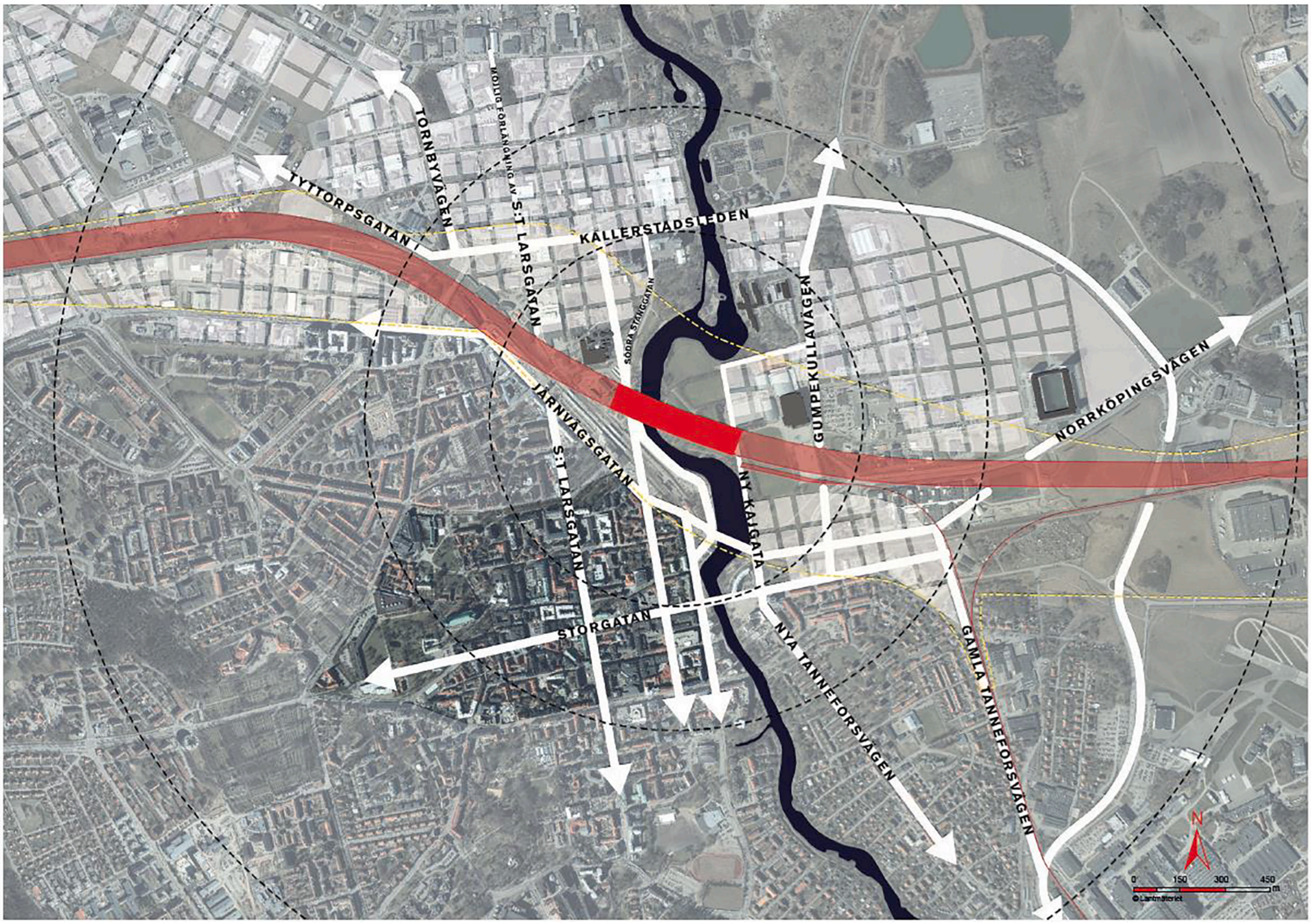

Fig. 5. The Stångebro corridor (Trafikverket, 2022c).

of [the Stångebro corridor]: if we don't get an agreement, then it will be Stångebro. Period. So yes, it's a process.

5.3. Work process

In this section, we present the interviewees' experiences of the work process with the BEA. The work process had three parts: (1) Defining the barrier effect analyses; (2) Selecting and creating input material for the barrier effect analyses; and (3) Communicating the results.

5.3.1. Defining the barrier effect analyses

Initially the results of the BEA were to be presented in a separate impact assessment report on barrier effects, comparable to a noise impact assessment report. However, through interactions between the BEA team and the practitioners using the analyses (hereafter called end-user) it became clear that the role of the BEA was to provide support to the impact assessments. Therefore, the setup of the BEA needed to be defined in close collaboration between the analysts and the end-users. Many participants from the ML and the consultancies stated that they would have preferred a more iterative work process where they could have tested and adjusted different setups of the BEA. This communication is needed to create the right focus for the BEA, as what is significant for the assessment of barrier effects might not necessarily correspond with the focus of the project in general (CO10).

5.3.2. Selecting and creating input material for the barrier effect analyses

The BEA required different types of input material, both in the form of existing GIS-data as well as material that needed to be created specifically. The work processes required for producing this material led to several challenges in the collaboration between the STA and the consultancies, as well as within the consultancies; issues that were more than just problems with gathering data for analyses. We have grouped these challenges according to the five determinants of barrier effects (see section 2.1).

5.3.2.1. Transport features. The characteristics of the railway and the station in the proposed corridors are mostly defined by technical requirements. However, these technical drawings could not be used for the BEA; rather, an architectonical investigation of the spatial impacts of the features on the built environments surrounding them was needed. At the start of the project, it was unclear to the STA and the project management team of the consultants how the spatial impacts in the different corridors could be assessed. The STA has no established methods for assessing the impacts of transport infrastructure in urban environments[1] (ST3) other than impact assessments related to noise and air pollution. In the route study in Linköping, the brief for the main consultancy in the project did not include the creation of a design for the station area. To CO10, it was clear that it would be impossible to assess the impacts of the corridors without developing detailed spatial design proposals for the station and railway. Therefore, the project management team invited an architectural firm into the project as a sub-contractor, to make

[1] Shortly after this case study was done, the STA published a method for 'integrated urban environment effect analysis of infrastructural transformations' (Berghauser Pont et al., 2022).

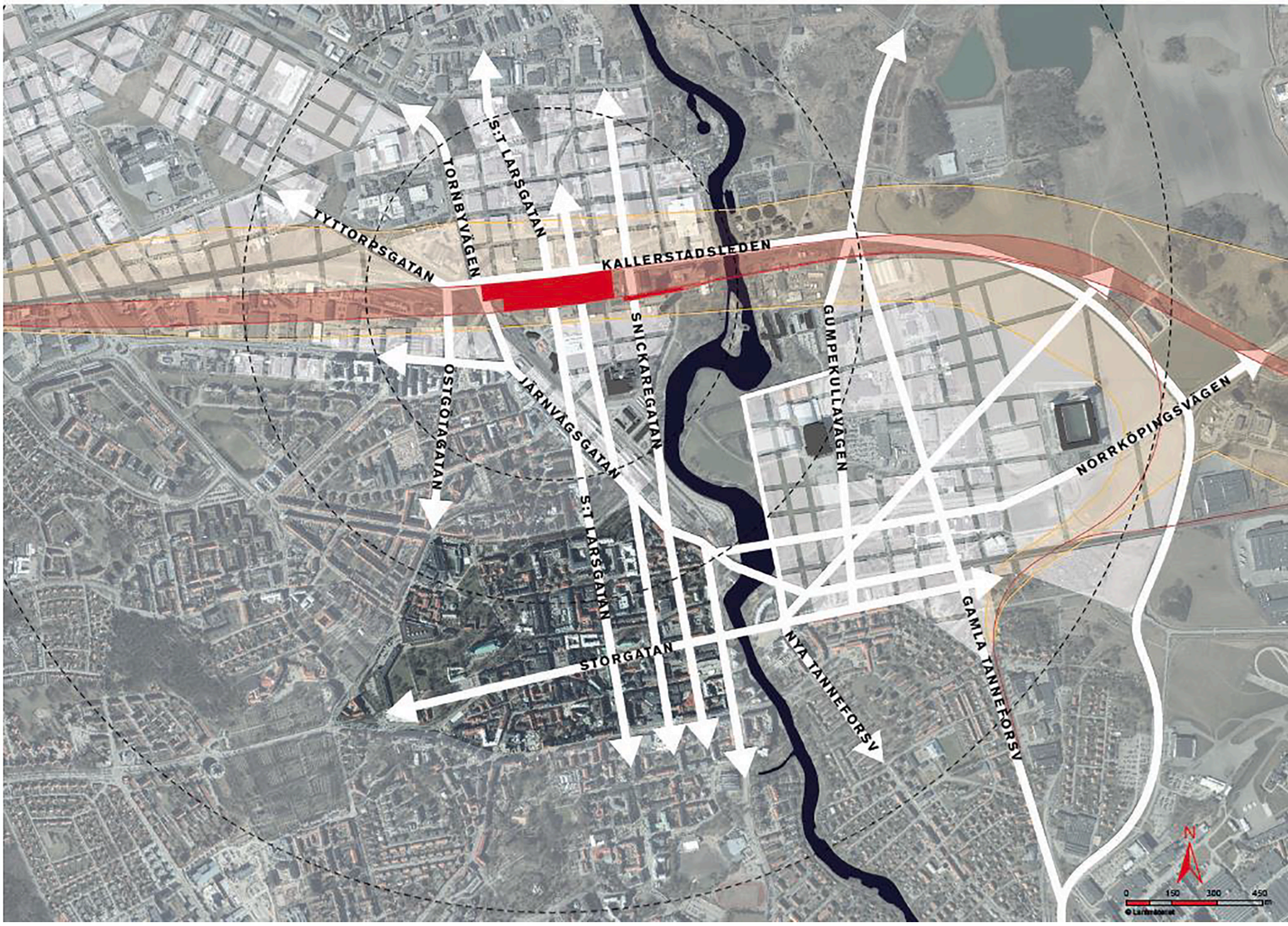

Fig. 6. The Steninge corridor (Trafikverket, 2022c).

proposals for the railway and station through maps, plans, elevations and 3D-visualisations. At a later stage in the project, these analyses of the spatial impacts of the railway in the city proved to play a prominent role in the process, causing CO9 to reflect that: "If I could redo this project, I think I would have put more focus in the beginning on making sure that everyone knows what a railway actually looks like, the place it takes, the height…".

5.3.2.2. Street network and crossing facilities. In the early stages of the planning process, the STA does not usually consider the adjustments that need to be made in the street network due to the new infrastructure, nor takes into account networks for pedestrians and cyclists. These networks are normally considered to be a municipal responsibility. In line with this, the assignment for the architectural firm was limited to developing planning scenarios for the station and its direct surroundings only. However, as CO10 and CO5 saw it, more was needed for assessing the impacts of the project on urban development:

> The architects and I saw from our background that we couldn't answer the question of how this would look like, what consequences this will have, if we were not allowed to investigate it. And then you have to sketch quite deeply to see if you even think it is possible to find a solution. And then this may not be the final solution, but if you can't find a solution, then you're kind of groping in the dark (CO10).

CO5 and her colleagues at the architectural firm chose to make urban development scenarios for the entire north -eastern part of the city, rather than the immediate surroundings of the station only (see Fig. 7 for an example). From their perspective, the street networks have the same function as the railway centre lines produced by the railway engineers, for estimating construction costs and for calculating noise levels. Like the railway centre lines, the street networks were only intended to function as input material for the BEA, describing plausible scenarios for urban development following construction of the railway and the station. This was appreciated by the officers from the ML, however, the representatives of the STA and some of the consultants were sceptical, as they considered scenarios at this geographical scale to be irrelevant to the project. CO5 reflected:

> I believe the STA often wondered what we were doing. They didn't understand anything about the meaning and use of these sketches. (…) There seems to be a lack of knowledge about what an architectural drawing is. A drawing is also an investigation, to see if something is possible.

The planning horizon for the adjusted street networks was another area of disagreement. The urban development scenarios created by the architectural firm had a 100-year planning horizon. However, CO3, CO7 and CO8 did not consider this suitable for their impact assessments. The STA's reference point for the assessments, according to their praxis, was the year 2040, the estimated completion date. Further, the architects had not considered the demands of motorised traffic (CO3). Therefore, anno 2040 versions of urban development scenarios had to be produced for these assessments. Due to lack of coordination and time restraints, this was done without any involvement of the ML. As the pivotal role of the street networks became apparent during the project, a majority of the officers at the ML and the consultants agreed, in hindsight, that these anno 2040 networks should have been developed by a working group

Fig. 7. The urban development scenario for the Steninge corridor (Trafikverket, 2022c).

involving all stakeholders.

Crossing facilities played a minor role in the assessments at this stage, as the STA applies a "one for one" policy in their infrastructure projects, meaning that every existing crossing facility is replaced with a new one, and a tunnel or a bridge is proposed for new crossings. However, in the next planning stage, the crossings will probably play a bigger role, and create an even stronger need for collaboration regarding the definition of the street network and the crossings. As expressed by ML5:

> We need to think whether we are satisfied with the "one for one" principle; we might want to invest in more crossings, because the railway is already a problem today. This [project] is the only opportunity to (…) get more crossings.

5.3.2.3. People's abilities. The analyses were based on pedestrian and bicycle networks as it is predominantly these slow modes that are affected by barriers. In only a few instances of the BEA, the qualities of the crossing facilities and the street networks were considered in relation to the ability to cross for particular social groups, for example, the assessment of segregation (Trafikverket, 2021b), where the abilities of people were considered through the identification of areas where residents are more vulnerable to barriers due to e.g. lower levels of car ownership. CO4 commented on the lack of consideration of differences in abilities of residents. The street network and the BEA were presented as a general representation of the built environment; however, what is commonly called 'general' often represents the perspective of able-bodied adult men. CO4 and ML2 noted a recognizable example of this, namely the way tunnels or desolate areas in the city create conditions for concern about personal safety, limiting freedom of movement for certain social groups. Nevertheless, these parts of the street network were still modelled in the same manner as the others.

5.3.2.4. Land use. An important part of the impact assessments was the selection of destinations. For the Traffic assessment (Trafikverket, 2022b) and the Architectural Program (Trafikverket, 2022d), the segments in the street networks functioned as generic representations of destinations. For the Recreation assessment (Trafikverket, 2022a), the destinations were selected by experts from the ML, the STA, and the consultants. The destinations for the Child Impact assessment (Trafikverket, 2021a) were selected by experts from the ML and the consultants, and verified through a survey among school children ($n = 780$). A more detailed description of the data used in the different BEA can be found in the Accessibility Impact Assessment (Trafikverket, 2021c). The fact that only existing land use was included in the BEA was experienced as a limitation by several officers from the ML, who felt the need for scenarios of what the city would look like in the future in terms of land use and urban development. ML7 perceived this as a fundamental problem that affects many of the STA's projects. This was confirmed by ST2, who explained that land use developments are not part of the STA's assignment.

5.3.2.5. Needs of people. Data on the needs of children to reach destinations was gathered through a survey; other estimations regarding the needs of people were based on expert judgements. It is important to be aware that this last approach only relates to potential needs. For instance, the BEA for Recreation showed conditions for reaching green areas, but does not give any information about the actual use of these areas (ML7). The geographical scale of the project and the diversity of social groups living there created huge challenges for estimating the needs of people. The railway and station will have impacts on the city that could last for more than a century, and it is difficult to foresee how the needs of citizens might evolve over time. Further, decision-making about the project is done by politicians, who must consider the needs of their voters and the needs of future generations. ML2 describes this situation as follows:

> This station will have its effect in 40 years, in 60 years, in 100 years. But [politicians] are just looking towards to the next election and then they want to put two park benches here and […] block off a street for bus traffic there. This is a huge challenge.

5.3.3. *Communicating the results*

The participants mentioned potential for improvements regarding the way the results of the BEA were presented. ML4 stressed the importance of the communicative phase of the BEA, in which the detailed maps need to be "scaled down" to emphasise what is important and to make them communicable to a broader audience. RE1 agreed, pointing out the limitation that many BEA lacked an indicator that would make it possible to compare the results and draw conclusions from them. The absence of threshold values for the BEA was also mentioned as a limitation. However, ML7 emphasised that the role of the analyses was not to provide final answers. The analyses themselves do not say what is good and bad; instead, the BEA constitute a basis for discussion where a qualitative judgement can be made, based on the results. Moreover, for grounded decisions to be made there is also a need to understand what exactly is being communicated. "A map often says: Hey, I'm trustworthy, look at me!" (CO4), but the results presented on a map are only valid and relevant if the right questions have been asked in the first place.

6. Discussion

In the interviews, the participants expressed their view that the BEA offered trustworthy support for impact assessments that was concrete, factual, and originating from what was seen as a 'third party'. STA was responsible for the analyses, however, the analyses also involved the interests of the ML. Their quantitative nature and the transparent work process created trust between the stakeholders, which is vital for information sharing and taking risks in collaboration (Huxham & Vangen, 2005). Based on this trust and on how the BEA encompasses the interests of both organisations, the analyses formed "a way of meeting" (ST4) and created a common language, which is important for collaboration (Gil Solá et al. 2018, Rye & Isaksson 2018). Under these conditions, the stakeholders were able to reach a consensus about a planning alternative.

The maps produced in the BEA did not function as standalone documents such as noise investigations and air quality reports but provided support for impact assessments in the project, and so are intimately connected to the questions of the impact assessments. Interaction was needed throughout the different stages of the work process between analysts and end-users, confirming the conclusions of Te Brömmelstroet and Bertolini (2010). The first phase was concerned with the definition of the analyses, and the model of barrier effects worked as a checklist for deciding on suitable types of analyses, and relevant social groups. Although the analyses only dealt with direct barrier effects, they provided additional support for analysing indirect and wider barrier effects.

The selection and creation of input material for each of the five determinants were central activities in the work process and involved several challenges related to inter-organisational and inter-disciplinary collaboration. The spatial impacts of *Transport features*, the railway and station, were hard to grasp for participants from both organisations, requiring some architectural competence for visualisation. It is fairly unusual that the architectural investigation of spatial impacts plays an active role in the early stages of infrastructure projects, rather than just visualising the final proposal.

The *Street network* constituted the main variable in the BEA. The pivotal role of this determinant was not obvious at the start of the project. The different versions of the street network that were needed for the analyses were created without collaboration with the stakeholders. The challenges here were to determine what geographical scale and which planning horizon were suitable for the analyses, and which modes needed to be considered. These challenges can be seen as examples of the difference in perspectives in this project- whereas the STA is responsible for the project up until completion, the municipality's main interest is from completion onwards (Enel, 1998). The STA was reluctant to be involved in the development of adapted versions of the street network, as the organisation needs to avoid additional costs to the project for consequences that the STA is not responsible for. This is also expressed in the "one for one" policy regarding how many crossings the STA is willing to finance.

The determinant *Land use* was related to the selection of destinations in the BEA. This selection was partly based on a survey among children, but for most BEA, destinations were defined using only expert judgement. As pointed out by Rajé (2007), assessments based on expert judgement may risk neglecting important aspects due to a lack of local knowledge and the absence of insight into the perspective of the specific social groups referred to. Likewise, the determinants *People's abilities* and *People's needs* were based only on expert judgement instead of dialogue with citizens. Thus, the perspective of the general public was neither included through a social impact assessment, nor through direct participation as stakeholders in the project. Insufficient dialogue with citizens can be seen as a missed opportunity for good governance (Rye and Isaksson, 2018). Further, the regional authority responsible for public transport in the region was invited late in the process and was not given the opportunity to include the concerns of public transport in the BEA. Consequently, the perspective of public transport was not incorporated in the BEA.

Lastly, the need for interaction between the analyst and the end-user was emphasised in the interviews. The results of the BEA need to be communicated to people who often lack the time and technical competence for interpreting the results. Therefore, a translation of the results into less technical language was needed. Further, there was discussion about the risk that maps look like they are presenting the truth without acknowledging the things that they do not show. It is important to be aware of how strategic documents can be disconnected from their author(s) and retain an authority of their own (Paulsson et al. 2018). Similarly, the results from the BEA in the shape of maps risk being disconnected from their input material and models once they are published.

6.1. *Limitations*

As this paper presents a single case study, the possibility to generalise its findings is limited. However, this not the intention of a qualitative study like the present one. Rather, the study captures different perspectives among practitioners working together on major transport infrastructure projects that can provide fruitful insights to other, similar projects and developments in the future. Another limitation relates to the fact that several participants mentioned how they experienced the BEA as coming from a 'third party', which may be related to the person who is doing the analyses being both consultant and academic researcher. As not every infrastructure project is the subject of a research project, this external character of the analyses must be discounted in the interpretation of the results.

7. Conclusion, policy implications and further research

In order to improve the applicability of existing assessment methods, van Eldijk et al. (2022) developed a conceptual model for and an overview of barrier effects analyses (BEA). In this paper, we present a case study of the use of those tools in practice, focusing on what the BEA contributed to the collaboration between stakeholders in the project. Our findings show that the BEA created a common language for discussing the impacts of the different alternatives. This created trust between the stakeholders and contributed to the reaching of a consensus between the parties for the preferred planning alternative, and turning what had become a trench war into a dialogue. It is essential that the analyst and the end-user interact during every stage of the process. *What* is analysed and *how,* need to be closely related to the questions of the impact assessment. Furthermore, as the street network is the main variable of the BEA, the adjustments in the street network are of great importance for the impact assessments. However, due to the differences in perspectives and areas of responsibility, challenges arose in the development of the alternative versions of the street network needed for the analyses.

Some future developments that may follow from this study can be pointed out. This project, and other projects where the BEA have been applied in practice, have attracted the attention of the Swedish transport sector. The case of the East Link in Linköping could lead to an increased awareness of barrier effects and to new standards related to the assessment of barrier effects. The model has already been integrated in the STA's method for impact assessments of transport infrastructure in urban environments (Berghauser Pont et al., 2022). Further, some policy implications and directions for new research can be indicated. As part of the transition to governance-based decision processes, there is a good reason for transport administrations and municipalities to reconsider the formal requirements of how barrier effects are assessed in transport infrastructure projects. These requirements relate to the need for more transparent and fact-based methods in which the crucial role of the street network needs to be acknowledged. The role of the street network can be compared to the role that railway centre lines play in, for example, noise assessment and calculation of construction costs.

Further research is needed to formulate methods for the development of alternative versions of street networks. Likewise, there is a need to develop methods for assisting municipalities in their role as stakeholder in large-scale infrastructure projects. Municipalities may lack experience of the processes involved and don't usually have access to the assessment tools they need. Additionally, developing a standardised work process with the BEA could reduce the need of interaction between analysts and users of the BEA. In turn, this could make the analyses quicker, cheaper, and potentially more trustworthy with more time for quality control. However, a fully standardised process may be less flexible and could lead to simplifications and aggregations that neglect the specificities of the project. Also, there is a need to develop principles related to which stakeholders with various interests must be included in the assessment of barrier effects and how they can be included. Lastly, we see a need for more case studies on the collaborative processes of barrier effect assessments, as this knowledge is a requirement for making the existing tools for the quantification of barrier effects more applicable in practice. The urgency of this focus is emphasised by Enel (1998), who concludes: "In many respects, the interaction between stakeholders seems to contribute more to the reduction or aggravation of the barrier effects than the physical configuration of the site or the technological solutions that are applied."

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CRediT authorship contribution statement

Job van Eldijk: Methodology, Writing – original draft, Writing – review & editing. **Anna Lundberg:** Writing – original draft, 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.

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Appendix A. – Interview guide

Introduction

- Thank you for participating.
- We will take a step back and reflect on how things have gone.
- Some words on my role as a researcher and as the one who has developed the indicators and carried out the analyses. Feel free to be honest in your evaluation of the indicators and how they have performed. Please also describe things that you and I already know.
- Purpose of the project: Knowledge about impact assessment of barrier effects; Contribute to better impact assessment of barrier effects of transport infrastructure.
- Research question for the study: What have the barrier effect analyses contributed to? How did the collaboration on the analyses work?
- Other interviews, handling the recording and transcription, sharing the article, publishing, and presentations.
- The interview has three parts: The work process, evaluation of the use and evaluation of the contribution to collaboration.

A. Description of the work process with the analyses (short answers please)

- Have you previously worked with a barrier in a project?
- What methods did you use then?
- How would you describe the collaboration between the municipality and the Swedish Transport Administration within the project as a whole?

B. Evaluation of use for assessment of goal-compliance

- Could you mention where in your work you found the analyses useful?
- Did the analyses provide new knowledge or insights?
- Could you describe what role the analyses have had in assessing goal achievement?
- Did the analyses facilitate opportunities to communicate about consequences and goal achievement? Any example?
- Have the analyses affected the way you work? Any example?
- Were there any challenges in using the analyses? Any example?
- Is there anything that you will bring to the next project? Any example?
- Is there anything that could be done differently in the next project? Any example?

C. Evaluation of contributions to the collaboration

- Have the analyses contributed in any way to the collaboration between the municipality, the Swedish Transport Administration, and the consultants? Any example?
- Have the analyses had any effect on the communication between the municipality and the Swedish Transport Administration? What role did they play at the goal achievement workshop in June?
- How was the internal collaboration around the analyses?
- Do you feel that you can trust the material and assessments contributed by other parties? Why or why not?
- Did the indicators make the impact assessment work more or less effective? Any example?

Closure

- Is there something you want to ask me?
- Who do you think I should interview other than those persons who I have invited already?
- Summary + interpretation + verification
- What did you think of the interview?
- Thank you for your time!

Appendix B – Themes and codes

Theme	Code category	Code	Description
What are the perspectives of participants on barrier effects?	Different perspectives on barrier effects	Conflicts of interest	Conflicts of interest between TRV and ML
		Project definition	
		Prognose-/goal orientation	Conflicts due to professional background
		Responsibility	What do the participants perceive to be the responsibility of their respective organisations? What do they perceive as the responsibility of others? How do they define the project?
How was the collaboration in the project?	Collaboration	Collaboration between consultants	
		Collaboration TRV-ML	
		Collaboration TRV-consultants	
		Collaboration ML-consultants	
How did the participants work with the analyses?	Working process	Working process	
What feedback did the participants have on the analyses?	Feedback	Limitations	
		Method development	
What did the analyses contribute to the collaboration between Trafikverket and Linköping kommun?	Understanding of the project	New insights about the alternatives	
		Nature and scope of the projects	
		Alternatives west of Stångån	
	General understanding of barriers	Interaction between barriers	
		Types of barriers	
		Influence on urban development in history	
	Support in communication	Objectivity	
		Pedagogic value	
		Equality	The analyses created more power balance between ML and TRV, i.e. more power for ML

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