CHALMERS

Traffic Land Use in Cities

A GIS-based Study of Traffic Space in Borås, from 1946 to 2010

Master of Science Thesis in the Master's Programme Design for Sustainable Development

AXEL PERSSON

Department of Civil and Environmental Engineering
Division of GeoEngineering
Road and Traffic Research Group
CHALMERS UNIVERSITY OF TECHNOLOGY

Göteborg, Sweden 2014
Master's Thesis 2014:11

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Examensarbete / Institutionen för bygg- och miljöteknik,
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Road network, railway and parking in central Borås, 2010. Picture is taken from the digitalisation process of traffic space in Borås, see Chapter 3. Case study: traffic space in urban Borås.

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ABSTRACT

With an increasing population and urbanization cities will be required to host more people, without straining the earth's resources in the same way as today. Urban traffic is an important part of that process and will play a big role in the development of more sustainable cities. For the last decades, traffic has been planned with cars in focus, which has led to traffic systems that make use of large amount of urban space. Some of that space could in other conditions be used for other purposes, such as housing and planned green areas. Included in the report is, besides a case study of traffic space in Borås, also a literature study of traffic space and urban density. The purpose of this Master's thesis was to study the development of traffic space in Borås, in the period 1946 to 2010. The purpose was also to compare the result of this study with a similar study made of traffic space in Lund. The case study was based on four aerial and ortho photos from different years, which were analysed with geographic informations system, GIS. The result was presented in four key figures, representing both traffic space per total urban area and traffic space per capita. The result showed that traffic space in Borås increased during the whole studied period. However, the increase was largest between 1964 and 1976. Space for parking showed the single largest increase, while for example space for railway decreased. The comparison with Lund, showed that the general trends in the two cities were very similar. Since Borås and Lund have rather different urban forms, the conclusion was that these trends also might hold for other Swedish cities.

Key words: Traffic, traffic space, land use, parking, sustainable development, Borås, Lund, urban density, geographic information system, GIS

Trafikens markanvändning i städer
En GIS-baserad studie av trafikyta i Borås, från 1946 till 2010

Examensarbete inom Masterprogrammet Design for Sustainable Development
AXEL PERSSON
Institutionen för bygg- och miljöteknik
Avdelningen för geologi och geoteknik
Forskargrupp Väg och Trafik
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SAMMANFATTNING

I takt med en ökande befolkning och urbanisering kommer städer behöva rymma fler människor, på ett sätt som inte frestar på jordens resurser som idag. Städers trafik är en viktig del i den processen och kommer spela en viktig roll i utvecklingen av mer hållbara städer. De senaste årtiondena har trafik planerats med fokus på bilen, vilket har lett till trafiksystem som gör anspråk på relativt mycket yta. Delar av den ytan kunde under andra omständigheter användas för exempelvis bostäder eller planerade grönområden. Inkluderad i rapporten är utöver en fallstudie av trafikyta i Borås, även en litteraturstudie av trafikyta och befolkningstäthet i städer. Syftet med detta examensarbete var att studera utvecklingen av trafikyta i Borås, mellan 1946 och 2010. Syftet var också att jämföra resultatet i denna studie med en liknande studie av trafikyta i Lund. Studien baserades på fyra flyg- och ortofoton från olika år, som analyserades med geografiskt informationssystem (GIS). Resultatet presenterades i fyra nyckeltal, som representerade både trafikyta per total tätort samt trafikyta per invånare. Resultatet visade att trafikytan i Borås ökat under hela den studerade perioden, men som mest mellan 1964 och 1976. Den enskilt största ökningen stod parkeringsyta för, medan till exempel yta för järnväg minskade. Jämförelsen med Lund visade att de generella trenderna var mycket likartade i de två städerna. Eftersom Borås och Lund har relativt olika stadsform, drogs slutsatsen att dessa trenden också kan gälla även för andra svenska städer.

Nyckelord: Trafik, trafikyta, markanvändning, parkering, hållbar utveckling, Borås, Lund, befolkningstäthet i stadsområde, geografiskt informationssystem, GIS

Contents

Preface

In this Master's thesis, the development of traffic space in Borås has been studied and compared to traffic space in Lund. The project has been carried out autumn 2013, at the department of Civil and Environmental Engineering, Road and Traffic Research Group, Chalmers University of Technology, Sweden. The study has been performed at Trivector Traffic AB, Gothenburg.

The author of this report has been Axel Persson, and examiner has been University Lecturer Gunnar Lannér. Jonas Tornberg has been supervisor at Chalmers, and Joachim Karlgren supervisor at Trivector Traffic AB.

I would like to thank the employees at Trivector, for welcoming me and providing me an office space. Especially my supervisor Joachim Karlgren, for his support during this project, as well as Lena Smidfelt Rosqvist who came up with the subject. I would also like to thank Gunnar Lannér and Jonas Tornberg at Chalmers, and Lars Strömqvist and the other employees at Borås Stad, who delivered data to the study.

Gothenburg, February 2014

Axel Persson

Glossary

Swedish translation of frequently used terms in this report.

English	***Swedish***
Accessibility	Tillgänglighet
Area	Område
Buffer space	Buffertyta
Car ownership	Bilinnehav
Impediments	Impediment
Mode of traffic	Trafikslag
Municipality	Kommun
Peak car	"Bilanvändningstoppen"
Road space for moving traffic	Vägyta för trafik i rörelse
Space	Yta
Space for parked vehicles	Yta för parkerade fordon
Space for railway	Yta för järnväg
The Swedish Central Bureau of Statistics	Statistiska Centralbyrån, SCB
The Swedish County Administrative Board	Länsstyrelsen
The Swedish National Land Survey	Lantmäteriet
The Swedish Transport Administration	Trafikverket
Traffic space	Trafikutrymme
Urban area	Tätort
Urban density	Befolkningstäthet i stadsområde

1 Introduction

An increasing population and urbanisation will require cities to host more people. To meet a sustainable future, this process needs to be done without straining the earth's resources in the same way as today. Traffic will play a major role in urban areas, concerning both space, energy and other environment issues. This Master's thesis includes theories of traffic and urban density, and a case study of traffic space in the Swedish city Borås. Moreover, it also includes a comparison between the result of the case study in this report, and an existing study of traffic space in Lund: "Hur stor plats tar trafiken egentligen?", written by Christine Karlsson in 2011.

1.1 Background

Historically, in the modern Western world, space and energy have not been a major problem and cities have been allowed to grow relatively unrestricted. The consequence is widespread cities with large car dependency and traffic systems that make use of a large amount of space. Some of that space could in other conditions be used for other purposes, such as housing, establishments and planned green areas. That would enable cities to host more people. Space efficient modes of transport, as public transport, bicycling and walking, would increase the efficiency of the traffic systems and at the same time reduce emissions.

One part of understanding how to make traffic systems more space efficient and more sustainable is to know how the traffic space look today and how it has developed over time.

1.2 Purpose

The purpose of this thesis was to study the development of traffic space in Borås, in the period 1946 to 2010. The purpose was also to compare the study of Borås with the study of traffic space in Lund, with a focus on sustainability.

1.3 Delimitations

The study concerned the urban traffic space of Borås. Traffic space in this study was defined as; space that direct or indirect is used by traffic. Furthermore, traffic space was divided in five main parts; road space for moving traffic, space for parked vehicles, space for railway, buffer space and impediments. These categories are further explained in chapter 3.1. Definitions of Traffic Space. Bus lanes and bicycle paths were not separated from car lanes.

The studied period ranged from 1946 to 2010 in order to include the entrance of major car use but still have access to qualitative data. The area that was analysed, was the urban area for each year, i.e. the size of the analysed area was different for each year.

1.4 Question Formulation

The questions below relate to the purpose of the report and are discussed and answered in Chapter 4 and 5.

- What were the major implications concerning the development of traffic space in Borås between 1946 and 2010. What consequences may that have had for a sustainable traffic system?

- In what way did the development of traffic space in Borås and Lund differ, and in what way were they similar? What conclusions could be made from this comparison?

1.5 Disposition

1. INTRODUCTION

2. LITERARY STUDY: TRAFFIC AND URBAN DENSITY

3. CASE STUDY: TRAFFIC SPACE IN URBAN BORÅS

4. DISCUSSION AND COMPARISON WITH TRAFFIC SPACE IN LUND

5. CONCLUSION AND FURTHER STUDIES

1.6 Method

As shown in the disposition, the report consists of five parts. Except for the introduction, each and one of them are explained below.

1.6.1 Literature study: Traffic and urban density

The literature study addresses the question; can a dense city with a space efficient traffic system, support a sustainable urban development? It also concerns the future development of global population growth and urbanisation, and why urban traffic will be important in a sustainable perspective. The literature study intends to provide a background to the case study.

1.6.2 Case study: Traffic space in urban Borås

The case study starts with a presentation of how the term traffic space was defined in this study. Thereafter, the procedure of the study is described in detail, as well as a presentation of the result.

To estimate the traffic space of Borås, GIS (Geographic Information Systems) was used. The study was focused on four years; 1946, 1964, 1976 and 2010. The period was chosen in order to include major entrance of cars but still have access to qualitative data. The study was based on aerial and ortho photos, provided by the City of Borås and The Swedish National Land Survey. Also digital data, tourist maps, and demographic statistics were used. The programs ArcGIS and Microsoft Excel were used to analyse the material.

1.6.3 Discussion and comparison with Lund

Four key figures were produced as a support to answer the question formulation. They provided an indication of how traffic space in the urban area of Borås has developed in the period 1946 to 2010, and were also a base for the comparison.

- Traffic space / urban area [%]
- Traffic space [m^2]
- Population / urban area [inhabitants / km^2]
- Traffic space / population [m^2 / inhabitant]

The key figures are presented as diagrams and are continuously followed by a discussion.

1.6.4 Conclusion and further studies

The last chapter includes a reliability analysis, examples of further studies in this topic and conclusion. In the conclusion, trends and patterns from the discussion are summarised, and the purpose and question formulation are verified.

2 Literature Study: Traffic and Urban Density

This chapter contains a literature study, which aims to be a background to the case study in chapter 3. The first part, chapter 2.1, addresses wide issues as future urban population growth; and briefly also how traffic has been planned in Swedish cities. In chapter 2.2, it is examined how a dense urban form and a space efficient traffic system, can affect traffic in a sustainable direction. Three main questions are studied; urban density and energy consumption, mobility versus accessibility, and space requirements for different modes of transport.

2.1 Urbanisation, Mobility and Traffic

All functions in a city are connected and need to work together to get a well-functioning, sustainable and liveable city. A traffic system is a prerequisite for urban accessibility and is a fundamental part in making a city function. This part of the report, addresses why cities and urban traffic will play a big role in the world's future development.

2.1.1 Increased urbanisation will require cities to host more people

It took 123 years for the world population to go from one billion to two billion but only 33 years to cross the three billion mark. The global population is growing and in 2011 the planet hosted seven billion people, twelve years after it reached six billion. Along with this rapid population growth, urbanisation is among the most significant global trends of the twenty-first century and signals a shift in scale and pace of global demographics (United Nations, 2011, p. 1).

The great, worldwide attractiveness of cities is grounded in access to jobs, education, services, functions, culture, etc (Trafikverket, 2010, p. 4). In 2007, for the first time, more than half of the global population was living in cities and that makes urban areas the leading habitat for mankind. This means that cities play a dominant role in global development and will be a key factor in sustainability processes (UN Habitat, 2012, p. 3). Despite the problems that can be associated with high urbanisation, it can potentially also be an instrument to overcome some of the current and future challenges.

According to the United Nation's report, World Urbanization Prospects, the world population are expected to increase by 2.3 billion between 2011 and 2050. In the same report, the population in urban areas is predicted to increase by 2.6 billion, from 3.6 billion in 2011 to 6.3 in 2050. Thus, cities will absorb all population growth the next 39 years and in 2050, 67 % of the wold population is expected to be urban (United Nations, 2011, p. 2). Today up to 70 % of the total greenhouse gas emissions can be derived to cities and the progression of urban areas will put new demands on urban and traffic planning (UN Habitat, 2012, p. 4).

2.1.2 Mobility and the development of society

Human mobility have been crucial in developing today's society. In the modern world enhanced mobility has led to increased welfare in terms of greater freedom, greater choice of geographic position of residence and workplace, better opportunities for business and transport of gods (Wahl et al., 2008, p. 19).

In the beginning of the 20^{th} century, the mobility in Sweden was rather low. The average distance travelled was about 200 kilometres per person annually, i.e. 0.5 kilometres per day. In the 1930s the mobility had increased to four kilometres per person per day (Wahl et al., 2008, p. 17) and in 2006 the average distance travelled was 40 kilometres per person per day (Sika, 2007, p. 5).

The possibility of mobilisation has also affected the look and size of cities. In a historical perspective there is a clear correlation between transport options and location of public functions. The pre-industrial cities were normally not larger than five kilometres in diameter and were characterised by a high urban density and geographical proximity. As technology has developed, the human travel patterns have changed. The railway and the car have provided new ways of transport, which have resulted in larger cities and more flexible ways of planning public functions. The entrance of car use accordingly decreased distances but in another way also created distances by decomposing the dense cities with mixed-use functions (Wahl et al., 2008, pp. 20-21).

2.1.3 Traffic planning in Swedish cities during the 20th century

After the Second World War, the car made the major entrance in Swedish cities. During the first half of the 1950s the amount of registered vehicles increased from 194 000 to 536 000 (Lundin, 2008, p. 17). The car was associated with freedom, success and independence, and became a symbol for the way out of the past and into a more bright future. It provided new opportunities and became an important part of the strong economic industrial period in the middle of the 20th century.

With the increase of cars, the number of accidents and congestion also raised. It was not considered possible to adjust the car use to the built environment of that time, hence the solution was instead to adapt the society to the car. American cities were set as an example of a modern way of planning and became the model of the technological development. Highways, parking and vehicle separation were ways to meet the new demands but in return large amounts of space were occupied and barriers for non-motorized road users were created (Lundin, 2008, pp. 90-91, 216). The expansion of car roads took place at the same time as the major demolition of late 1800s and early 1900s buildings in Swedish cities. This allowed further opportunities to plan commerce and commuting to a life with a car, demolition sites could additionally be used as parking (Lundin, 2008, pp. 54-57).

There existed some kind of social consensus that the car was a fundamental part of the future. One consequence was that the traffic system was designed to support the future needs when greatest. Thus, the traffic system was dimensioned to be able handle the maximum capacity during a day, 10 to 20 years ahead. This lead to an over capacity during a long period, but it also generated traffic that in other conditions not would exist, or exist in other forms (Linderholm et al., 2009, p. 1).

2.1.4 Peak car: A future declination of car use in the Western world

In contrast to the mid 1900’s great expansion of car traffic, many Western countries today have a low growth of car use. In some countries, especially in urban areas, it is declining. The trend in the last couple of years are most likely influenced by the world economic problems that started in 2008, but these trends seem to go back even further (Goodwin, 2012, p. 1). Some researchers argue that the Western World is in a phase of peak car and that the car in the future will have another role. Peak car can be derived from many different factors; improved public transport, densification of cities, increased fuel prices and a reduced importance of car as a status symbol (Göran Nilsson, 2013).

2.2 Space Efficient Urban Traffic

The approach to traffic planning described in chapter 1.1.3, "Traffic planning in Swedish cities during the 20th century", has resulted in systems that promote traffic with large impact on the planet's resources. Current level of car use generate high fossil fuel consumption and hence large emissions.

With a more space efficient traffic system, areas that today are occupied by traffic could instead be used for housing, establishments or planned green areas. One advantage of densification instead of development of new areas, is that already existing infrastructure can be used. There would also be possibilities for shorter distances to important destination points and existing social functions, which would make it possible to walk, bicycle and use public transport to a higher extent (Linderholm et al., 2009, pp. 6-7).

The general theory in the literature, is that a dense city supports sustainability. However, the relation between urban form and traffic is complex, and it is debated what difference this theory makes in practice (Hickman et al., 2005, p. 117). Besides different types of land use planning, such as densification, also socio-economic characteristics influence travel patterns. Income, car ownership, employment status, gender, age and household size are factors that increase the difficulty in relating land use characteristics and travel patterns (Stead et al., 2000, pp. 174, 186). Change of urban form is a slow process with a wide range of stakeholders, but clearly, there is a relationship between the way space is planned and how people use it. Physical form, in terms of infrastructure and buildings, can in certain locations have a major impact on travel patterns over time (Williams, 2005, pp. 2-3).

Summarised, a dense city with a space efficient traffic system, is not in itself sustainable. However, it provides possibilities for other modes of transport than car. Most cities that are successful in achieving a high share of pedestrian, bicycle and public transport have worked for a sustainable development over time. They have stepwise developed the traffic system and urban form; often also combined with information arrangements (Smidfelt Rosqvist et al., 2010, pp. 16-17).

This section of the report addresses why a space efficient urban traffic system can be positive in a sustainable perspective. It considers how urban density affect traffic and what influence that may have on energy consumption and sustainability.

2.2.1 Urban density and energy consumption

In 1989 a study was done, in order to relate a number of parameters to passenger transport (Newman et al., 2000). The study shows that there are very strong correlations between automobile use, or private transport energy use, and parameters as length of road, parking provision, level of public transport use and public transport speed to traffic speed ratio. However, the strongest correlation turned out to be between automobile use and urban density, see Figure 1. The diagram shows that American cities, in 1990, had about half of the urban density as European cities and about three times as high private transport energy use per capita. In dense cities in Asia on the other hand, the private transport energy use per capita was yet about six times as low as in American cities (Newman et al., 2000, p. 113). Considering that transports are one of the sectors that emit largest amounts of carbon dioxide (Smidfelt Rosqvist et al., 2010, p. 8), these are essential numbers.

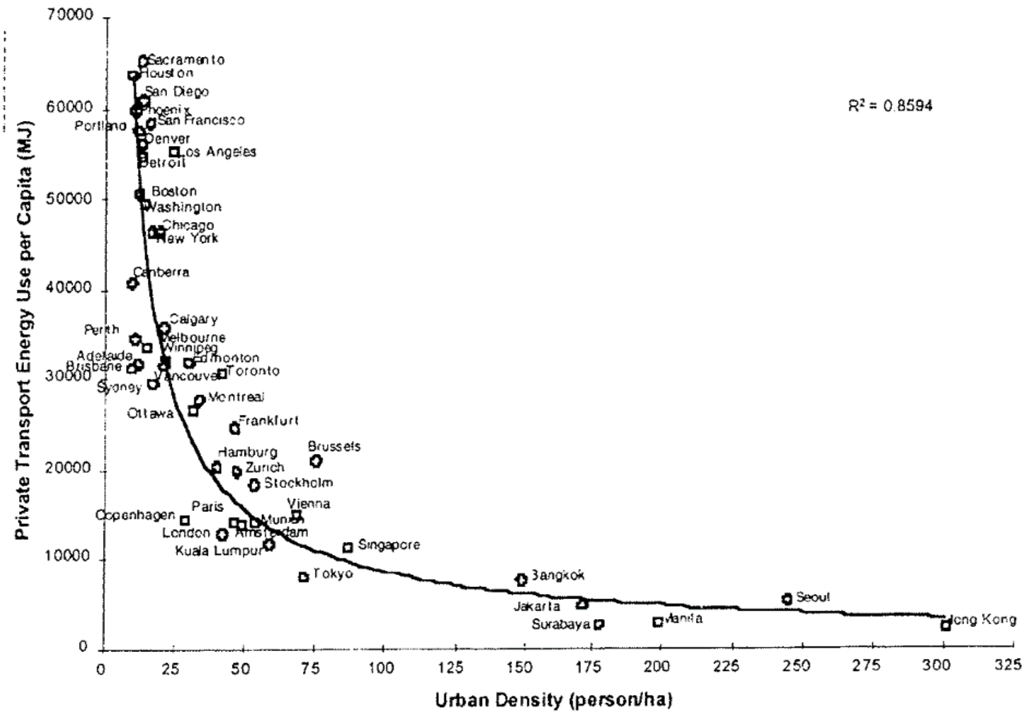


Figure 1. Private transport energy use per person, by urban density, 1990 (Newman et al., 2000, p. 113)

The result, that cities with low urban density use more private transport energy can be derived to a greater automobile dependence. The occurrence can be seen as a vicious circle; car use requires large road space, hence a low urban density and a traffic system that demand cars in order to travel convenient. Further, data in the study shows that there is no clear or systematic relationship between car use and wealth. Growing wealth does not i.e. have to lead to increased automobile dependency (Newman et al., 2000, p. 111).

2.2.2 Mobility versus accessibility

Historically, many problems associated with mobility have been able to be solved or reduced by technology. Higher capacity of the road system, introducing the catalyst and removing lead from gasoline are examples of actions that have given car use possibility to spread (Banister, 2008, p. 75). But issues that in present time are related to cars; such as safety, noise, congestion, land requirements and interference with other functions will be harder to solve with technology. In fact, these problems would remain even if the vehicles were carbon neutral (Banister, 2009).

In order to overcome these problems it will be necessary to plan for improved accessibility instead of improved mobility. The goal of transport is accessibility; the ability to reach something desirable. Mobility on the other hand is a way to achieve accessibility. Since the actual transport is the factor that costs money, the desirable outcome would be to have as much accessibility per mobility as possible (Ross, 2000, p. 14).

Long distances and localisation that requires automobile transport increase mobility for the group with access to car. However, the accessibility in general would decrease, especially for the group with no access to car (Smidfelt Rosqvist et al., 2010, pp. 9-10).

2.2.3 Different modes of traffic require different amount of space

A general trend for cities the last century have been emerging low dense suburbs around the city centres, referred to as urban sprawl. As discussed earlier in the report, this type of urban form promotes increased automobile dependence. It also creates a problematic situation for public transport provision, due to widespread catchment areas. More dense catchment areas creates better conditions for an efficient public transport. Furthermore, a city with less urban sprawl can together with appropriate infrastructure support bicycle and walking conditions in a better way. Increased use of public transport and decreased car use will also reduce noise and emissions (Nijkamp et al., 1996, pp. 190-191). That will have a positive impact on the liveability factor in the city, which can promote bicycle and pedestrian traffic additionally.

There are also differences in how much space different modes of traffic require when in use. The diagram in Figure 2 displays how much space that is required for different modes of transport in Norwegian cities. A car claims more than the double amount of space than a bike, more than ten times as a bus and almost 20 times as much space as a tram (Haatveit, 1987). Moreover, cars require large space when parked and they are in average parked 96 % of their lifetime (Lundin, 2008, p. 48).

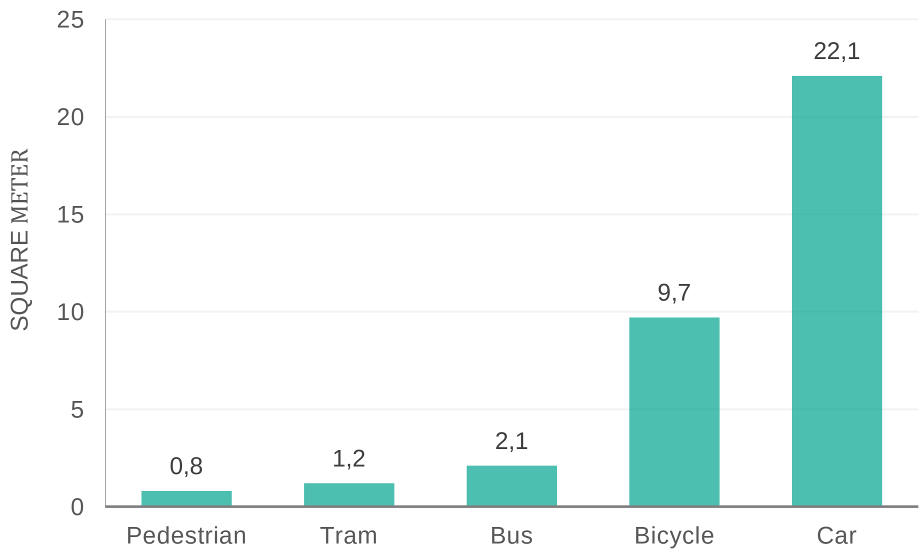


Figure 2. Required space for different mode of traffic, at normal occupancy (Haatveit, 1987, edited by Author).

3 Case Study – Traffic Space in Urban Borås

This chapter starts with a presentation of the definition of the term traffic space and a brief presentation of Borås. After that it is described how the study was executed and what parts it consists of. At the end of the chapter the results of the study are presented.

3.1 Definition of Traffic Space

Regardless the effectiveness of an urban traffic system, space is needed to make it function. Traffic space was in this study defined as; Space that directly or indirectly is used by traffic. The term was in this study be divided into five main parts:

- Road space for moving traffic
- Space for parked vehicles
- Space for railway
- Buffer space
- Impediments

Below, the five types of traffic spaces are briefly explained. They are also, except for railways, illustrated in Figure 3. More about how the different categories are defined can be read in Chapter 3.4. Digitalisation and Calculations.

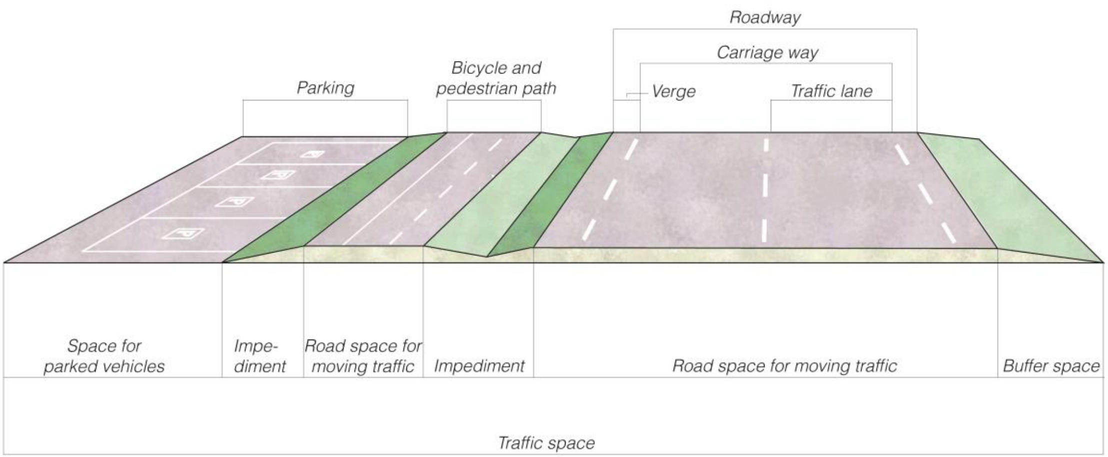


Figure 3. Schematic presentation of how traffic space was defined in this study. The categories impediments and buffer space do in reality sometimes overlap, read more in Chapter 3.1.5. Impediments. In this figure, the green stripes between the hard surfaces are defined as impediments and the one outside the road is defined as buffer space.

3.1.1 Road space for moving traffic

The Swedish road network is divided in public roads, national or local, and private roads. The Swedish Transport Administration administrates the national roads and each municipality administrates for their local road network (Trafikverket, 2013).

In this study, road space for moving traffic included roads, bicycle paths and walkways. No distinction was made between them in this study.

3.1.2 Space for parked vehicles

Parking areas are necessary to house vehicles not in use. Parking is defined as: A placing of vehicles with or without driver for any other reason than as 1) a result of traffic conditions, 2) to avoid danger, or 3) takes place for embarkation or alighting or loading and unloading of goods. A space for parking is an area designated for parking (Trafikverket, 2012, p. 23).

Car parking can exist in multiple levels in a parking garage, in single levels in buildings with other purposes or as ground parking. Ground parking can occur as larger areas with several lots, individual parking on private property and parking along a road. Parking in garages was in this study referred to as concealed parking. In general, only parking that was possible to distinguish from the aerial and ortho photos was included in this study.

Including space for entrance and exit, a car occupies 25 square meters when parked in ground level, while a bicycle claims around 1.5 square meters. Buses do not need parking in the same way as cars and bicycles, but requires on the other hand space for bus stops and depots when not in use. A normal bus occupies around 30 square meters when parked (Karlsson, 2010, p. 10).

3.1.3 Space for railway

The railway makes use of space where the tracks lead in and out of cities. Stations and depots also make use of space in central areas. Except for the space that the railway tracks make use of, railways also require a side area that in most cases cannot be used for any other purposes. These side areas were also included in this study.

3.1.4 Buffer space

Buffer spaces provides protection from emissions, traffic noise and accidents, and should normally not contain buildings. The Swedish County Administrative Board regulates widths of buffer spaces, to be consistent with traffic noise and safety standards. Thus, the width depends on speed limit, traffic volume, proportion of heavy traffic and function of nearby buildings (Karlsson, 2010, pp. 11-12). The fact that buffer spaces not can be developed for other purposes made them included in traffic space.

3.1.5 Impediments

Traffic also claims space by occupying areas inside the traffic system (Linderholm et al., 2009, p. 2). These areas, which are called impediments, are blocked for other purposes due to practical reasons, such as shape, size and barriers. Impediments can for example occur in crossroads, traffic circles and between road lanes (Karlsson, 2010, p. 12).

The definition of buffer space and impediments do sometimes overlap. In this study, buffer spaces were the areas along wider roads, the rest were impediments. More information of how these categories are defined in this report can be read in Chapter 3.4.7. Calculation: Buffer space and 3.4.8 Calculation: Impediments.

3.2 Borås: History, Geography, Demography

Borås was founded in 1622 and is located in the southern part of Västergötland, see figure 4. The development of the city accelerated in the middle of the 19th century, with a strong textile industry. Along with that, the population of the urban area of Borås increased rapidly and in 1950 it was the ninth largest city in Sweden. After that the textile industry has been mixed with other industries (Nationalencyklopedin, 2013) and the population have been varying, see Figure 4. A slowdown in the local textile industry was the reason behind the population decrease between 1970 and 1990 (Borås Stad, 2010b). In 2010 the urban area of Borås had a population of 66 273 inhabitants (Statistiska centralbyrån, 2010).

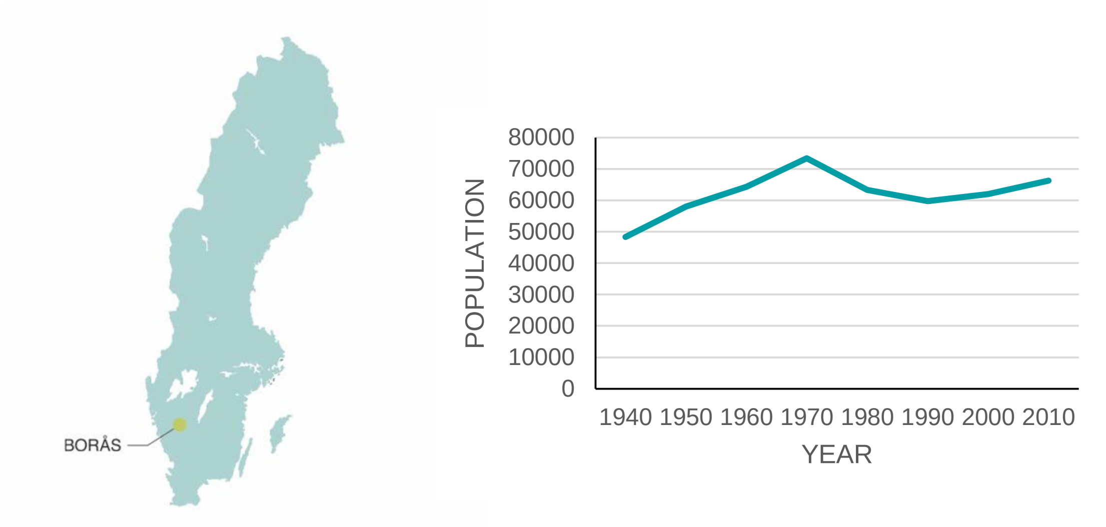


Figure 4. Geographic position of Borås (left) and population statistics of the urban area of Borås[1] (right) (Statistiska centralbyrån, 1969 p. 63, 2009 p. 31, 2010 p. 38).

The city centre, which is the oldest part of Borås, is planned in a grid. The city has historically grown in all directions but in recent years mainly along road 40, which runs through the city from west to east (see Figure 5). Borås has railway connections to the south, west and north.

3.3 Borås Visions and Strategies

"Borås 2025" is the vision of the future, desirable Borås (Borås Stad, 2013). To reach that vision a number of strategies have been formulated. Several of those strategies concern urban and traffic planning, and are summarised below.

Borås wants to densify the city centre and create a mixed-use area of housing, retail and offices. The goal is to triple the number of inhabitants in the city centre, from 2012 to 2025. Parts of the city centre are intended to be car free and public transport systems should be dominating (Borås Stad, 2012b). Moreover, it should be easy to move between different parts of the city by bicycle or walking. The inhabitants use public transport in a greater extent and the transport systems to Gothenburg are further developed (Borås Stad, 2012a).

[1] Note: Not the municipality of Borås.

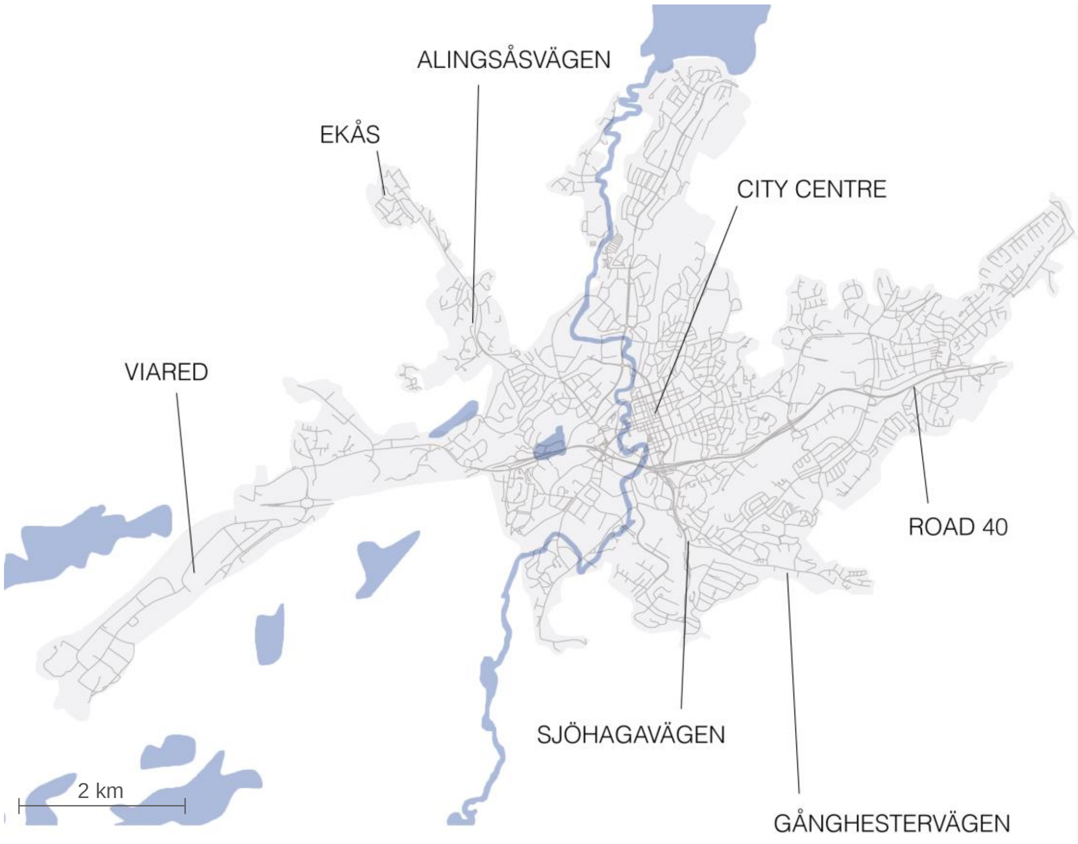


Figure 5. Map of Borås urban area[2], 2010.

3.4 Method: Case Study

Measurements and digitalisations in the case study were made with the program ArcGIS. Calculations were done with ArcGIS and Microsoft Excel. In order to make an accurate comparison with the traffic space in Lund, the method in "Hur stor plats tar trafiken egentligen?" was studied (Karlsson, 2011, pp. 40-53).

The data that was used in this study, originated from the City of Borås and from The Swedish national land survey. The main material consisted of two aerial photos, from 1946 and 1976 (Lantmäteriet, 1946, 1976), and two orthophotos from 1964 and 2010 (Lantmäteriet, 1964) (Borås Stad, 2010a). Thus, the analysis started with 1946 and ended with 2010. The intention was to have an even distribution of data over the time period. However, due to limited access to data, some adjustments had to be done. Figure 6 shows how the studied years were distributed. These years correlated relatively well with the studied years of Lund, which were 1940, 1965, 1978 and 2010.

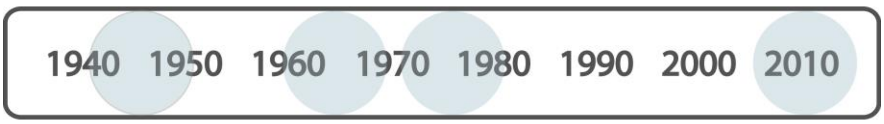


Figure 6. Years studied in Borås: 1946, 1964, 1976 and 2010.

[2] Note: Not the municipality of Borås

Figure 7 shows example of the quality of the aerial and ortho photos. The coordinate system SWEREF 99 13 30 was used on all photos, and the two aerial photos had to be georeferenced manually. To make a consistent analysis they were all used in scale 1:1250, no matter of individual quality. The scale was chosen with regard to the photo with lowest resolution. In order to get a reliable analysis regarding the development of the traffic space, estimations and generalisations were consistently used through the entire study.

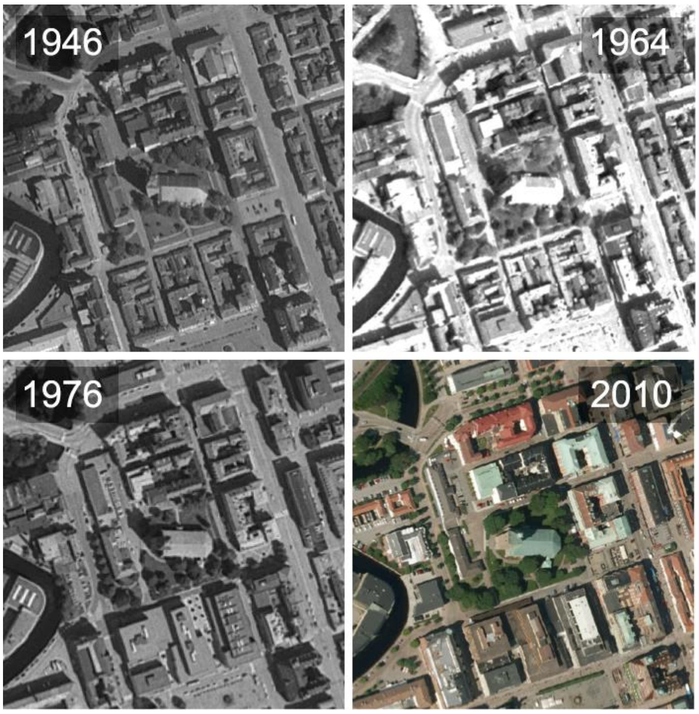


Figure 7. Example of the quality of the aerial and ortho photos used in the study (Lantmäteriet, 1946, 1964, 1976) (Borås Stad, 2010a).

Key figures in the case study

The four key figures that are listed below, were the outcome of the case study. Together, their purpose were to give an indication of how traffic space in the urban area of Borås developed during the period 1946 to 2010. They were also chosen to be able to make a relevant comparison with the traffic space in Lund.

- **Traffic space / urban area [%]**
  This value indicates how traffic space has changed in relation to the urban area in total.

- **Traffic space [m^2]**
  This value indicates the total amount of traffic space in urban Borås. An absolute value of how spaces used by traffic have grown from 1946 to 2010.

- **Population / urban area [inhabitants / km^2]**
  This value indicates the urban density of the city.

- **Traffic space / population [m^2 / inhabitant]**
  This value indicates how the amount of traffic space has changed in relation to the population.

3.5 Digitalisation and Calculations

This section describes how the digitalisation of traffic space was done. GIS-layers were created for each category of space and then they were summarised in Microsoft Excel. The outcome are presented in tables at the bottom of each sub-chapter. This data was used to produce diagrams, which are presented in the discussion. The numbers in the tables were rounded to the nearest tens, and only the space within the urban area of each year was analysed. The study did not include unfinished areas. Figure 8 shows an example of how the polygon layers in GIS looked like.

Figure 8. Example digitalisation 2010. Roads: green, parking: pink and railway: blue.

3.5.1 Calculation: Population

The population statistics are presented by The Swedish Central Bureau of Statistics, SCB, every fifth or tenth year (Statistiska Centralbyrån, 1969 p. 63, 2009 p. 31, 2010 p. 38). These values were interpolated to get the population for the years analysed in this study. Table 1 shows the population used in the calculations in this study.

Table 1. Interpolated population Borås.

Year	Population
1946	54 141
1964	68 797
1976	66 684
2010	66 273

3.5.2 Car ownership in Borås and Lund

Table 2 shows the development of car ownership in Borås and Lund. It only ranges from 1974 to 2010 due to lack of data. It is also important to emphasise that the figures represent the whole municipalities and not just the urban areas.

Table 2.Car ownership in the municipalities of Borås and Lund (Statistiska Centralbyrån, 2013).

Year	Cars/1000 inh. Municipality of Borås	Cars/1000 inh. Municipality of Lund
1974	339	322
1980	358	335
1990	436	372
1995	422	353
1998	458	368
2000	454	376
2005	462	376
2010	462	370

3.5.3 Digitalisation: Urban area

As presented earlier, the studied area was the urban area of Borås. The Swedish Central Bureau of Statistics, defines an urban area in Sweden as an urbanised area with at least 200 inhabitants and where the distance between the buildings do not exceed 200 meters. The distance can in some cases be allowed to exceed 200 meter when it comes to a larger city's sphere of influence. It can also exceed 200 meters when the area between the buildings is used for public purposes, such as roads, parking, green areas, sport fields and etc. If the border between urban and rural land is diffuse, this distance can in some cases also be less than 200 meters (Statistiska Centralbyrån, 2009, p. 83).

The urban area of 2005 and 2010 was provided in shape files from the City of Borås and SCB provided the urban area of 1980. Older boarders are not stored in digital format, why the urban area of 1946, 1964 and 1976 had to be digitalised manually. In these cases the definition from SCB was used to make accurate estimations of the urban areas.

The digitalisation was made by analysing the aerial and ortho photos from each year, as well as analysing the existing urban area borders. As support, an overview map from 1977 (Borås Stad, 1977) was used and also three tourist maps from 1949, 1965 and 1978 (Borås Stad, 1949, 1965, 1978).

In two cases the aerial photos did not cover the entire urban area. In the northwest part of the aerial photo of 1946, the area Ekås was outside the frame. The architecture of the buildings indicate that the main part of the area was built after 1946, and it was therefore assumed that Ekås was not a part of the 1946 urban area. The other case was the southwest part of the aerial photo of 1976, where the industrial area Viared was outside the frame. Here, the overview map from 1977 (Borås Stad, 1977) indicated that Viared was not finished in 1977. Thus, it was assumed that this area was not at part of the urban area in 1976.

The result of this digitalisation was four different polygons, representing the urban area for each year, see figure 9. The areas then were calculated in ArcGIS, see table 3.

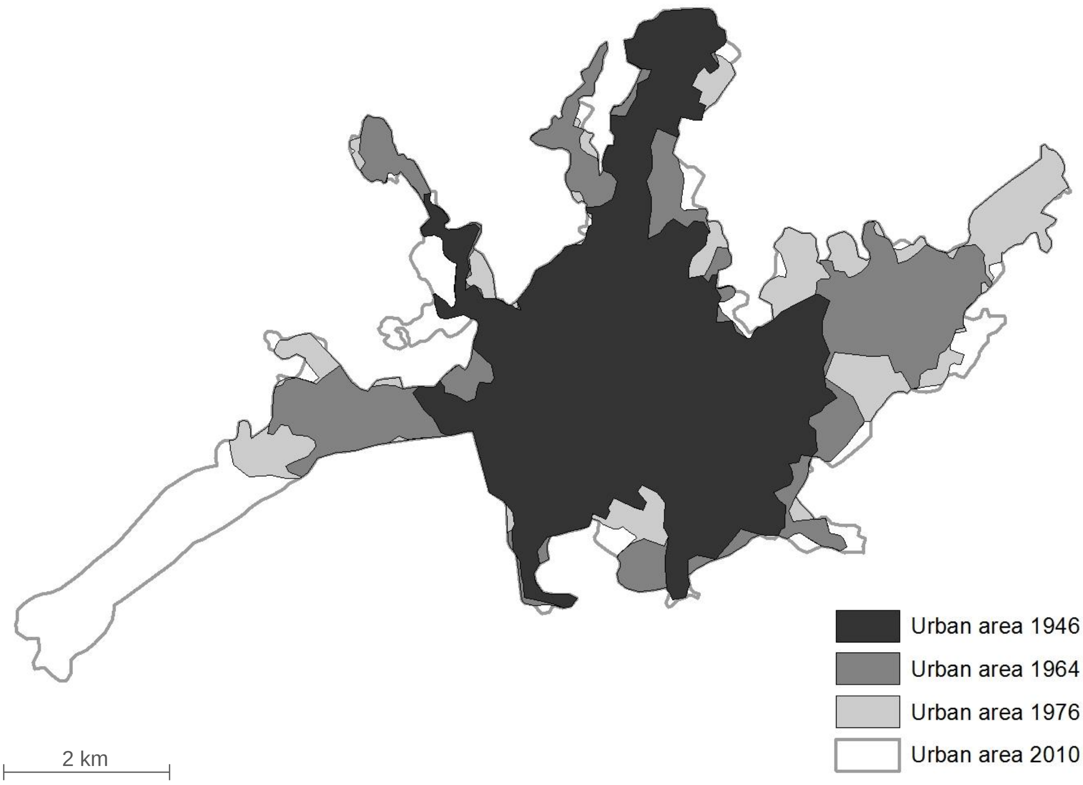


Figure 9. The development of Borås urban area. The darkest area represents the urban area of 1946 and the brightest represents the urban area of 2010.

Table 3. Borås urban area in square meters.

Year	Urban area (m²)
1946	16 366 500
1964	23 501 540
1976	27 517 540
2010	32 002 590

3.5.4 Digitalisation: Road space for moving traffic

In order to make the process of the digitalisation of roads more clear, this part is divided in three steps; digitalisation of the road network, creating buffers, merging buffers. This procedure was then repeated for all studied years. The analysis was done in the order: 2010, 1976, 1964 and last 1946.

Road network and road widths

To calculate the area of road space for moving traffic, a road network including road widths was needed.

Two digital files containing road networks of urban Borås were received from the City of Borås. They are in this report referred to as NVDB_1 and NVDB_2. An excel file was also received, which contained tables with areas of road segments managed by the City of Borås, see table 4.

Table 4. Input files, for calculating road space for moving traffic.

Name	Type	Description
NVDB_1	Shape file	Road network, roads managed by The Swedish Transport Administration. Road widths as attribute
NVDB_2	Shape file	Road network, all roads. No road widths
Road_data	Excel file	Tables with areas of road segments, managed by the City of Borås.

NVDB_1 contained roads managed by The Swedish Transport Administration, with road widths as attribute. NVDB_2 contained a road network with all roads but lacked road widths as attribute.

The excel file was linked to NVDB_2, to get the areas of the roads as an attribute in ArcGIS. By calculating the road lengths in ArcGIS and then divide areas by lengths, widths were achieved. In those cases where widths of the two files overlapped, the widths from NVDB_1 were used.

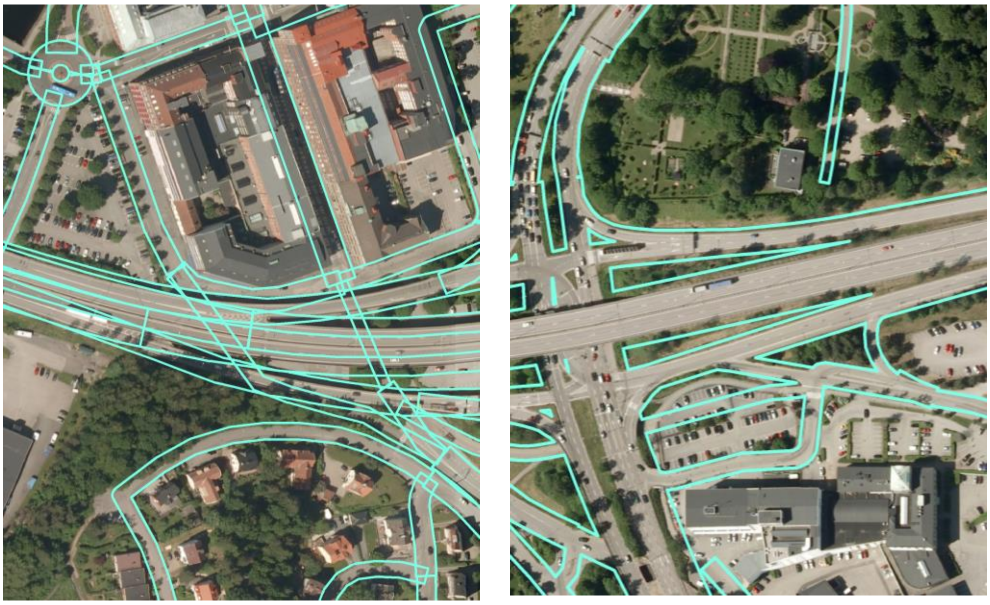
Due to the inconsistency in the excel file, a few road segments still lacked widths. Those segments were copied to a third layer [NVDB_3] and their average width was estimated to 6.7 meters. Now, the roads in urban Borås were completely covered by a digital road network, with road widths as attribute.

Creating buffers

To calculate the area of the roads, buffers were created around the road networks. The buffers were created to correspond to the widths in the attribute tables. Some widths were found to be to wide, and were therefore edited to match the underlying ortho photo.

Merging buffers

One buffer is created around each road segment. That resulted in many overlapping areas, which would lead to an overestimation of the space. To solve that, all buffer polygons in each layer were merged, see Figure 10. After that, also the three different layers were merged to get one layer and one polygon. The result was one polygon covering all roads in the urban area of Borås and the area could then be calculated in ArcGIS.



Figur10. Example of how the road polygons were merged in order to not overestimate the area. The left side is before merging the polygons and the right side is after. Displayed in the ortho photo from 2010 (Borås Stad, 2010a).

Repeat procedure for all studied years

The road network from 2010 were then copied to the photo of 1976, where they were edited to match the underlying photo. After that the road network from 1976 were copied to the photo of 1964, and so on. Below, it is described what main modifications that were done on the road network in respective years.

1976

There were not so many differences in the road network between 2010 and 1976. Some larger roads were narrower in 1976. Hence, the widths of these roads had to be decreased in the shape file of 1976 compared to the shape file of 2010.

1964

The step from 1976 to 1964 implied more differences. New roads had been built and old had been taken away. Here, the width of several road segments had to be narrowed or deleted. Roads that existed 1964 but not in the road network from 2010 were added and the average width of these roads were estimated to 5 meters.

1946

Same procedure as for year 1964. With the exception that the estimated width of roads that were added was 3.4 meters.

Table 5. Road space for moving traffic, Borås

Year	Road space for moving traffic (m^2)
1946	1 418 740
1964	2 271 840
1976	2 918 420
2010	3 425 910

3.5.5 Digitalisation: Space for parked vehicles

Space for parked vehicles was calculated by creating polygons around all visible parking within the urban area of Borås, see Figure 11. The spaces included in the study were the ones that were possible to distinguish from the aerial and ortho photos. Also entrances and exits to the parking lots were included. Single parking on private property was not included and neither was concealed parking, with exception if it was obvious that the building was only used for parking.

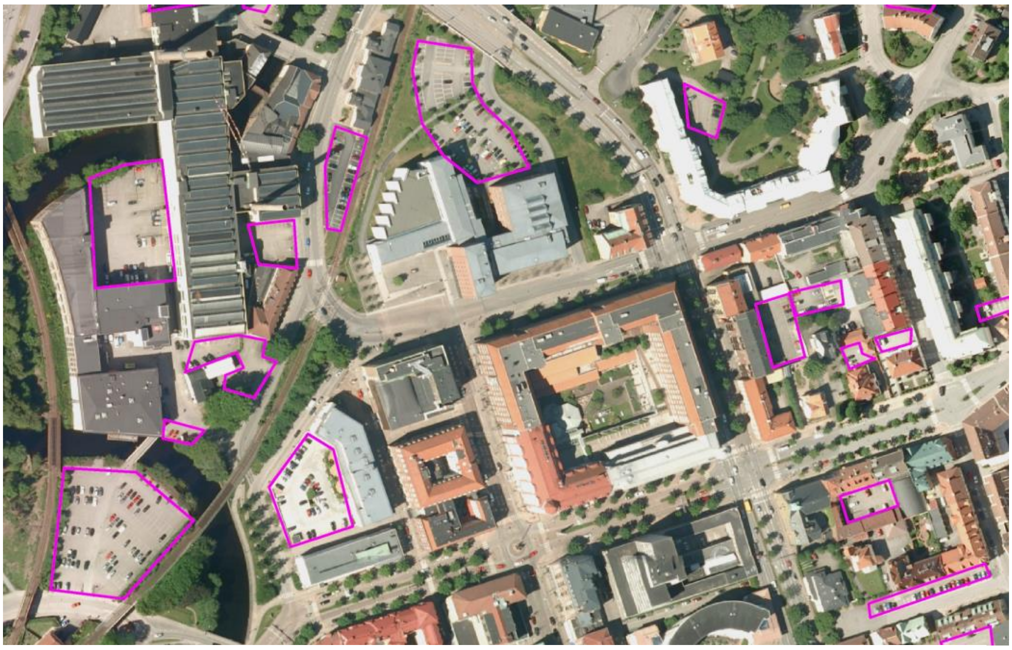


Figure 11. Example of how space for parked vehicles was digitalised. Displayed in the ortho photo from 2010 (Borås Stad, 2010a).

Industrial areas are in a large extent covered by hard surfaces. In this study, only spaces clearly used for parking were included. In cases where the difference was hard to distinguish, the space was rather excluded than included. Photos with low resolution made this consideration more difficult.

The procedure started with digitalising parking lots in a GIS-layer on the ortho photo from 2010. This layer was then sequentially copied and edited to match the other photos.

Table 6. Space for parked vehicles, Borås

Year	Space for parked vehicles (m^2)
1946	74 790
1964	455 060
1976	935 160
2010	1 339 810

3.5.6 Digitalisation: Space for railway

Included in space for railway, were both the space covered with tracks but also the side area that cannot be used for any other purpose. Where the railway track runs through built environment, it was possible to measure how large this area was. A reasonable estimation from the ortho photo of 2010 gave an average value of 12 meters from the centerline to the end of the side area. Thus, a buffer with the total width of 24 meters was created on the railway track. Since the railway has not been changed in large extent, this value was used for all years. Other areas that are used by the railway, are station areas and depots. In these cases, polygons were created to be able to measure the area. The different polygons were then merged in the same way as the road network, which is described in Chapter 3.4.2. Thereafter, the total space used by railway could be calculated in ArcGIS. To not overestimate the space in crossovers, only the roads were counted, where roads cross railways.

Table 7. Space for railway, Borås.

Year	Space for railway (m^2)
1946	355 510
1964	396 850
1976	413 300
2010	410 570

3.5.7 Calculation: Buffer space

It would not have been possible to measure the exact buffer width of all roads in Borås. Thus, this part was delimitated to estimations of the buffer spaces of the larger roads. The buffer widths was estimated by measuring the distance to the closest physical structure from the road every 300 meter, see Figure 12. Then the largest and the smallest value were disregarded, and a mean value was calculated. The buffer space was then studied visually, in order to investigate if the mean value was a reasonable assumption. Since the roads have been changed between the years of investigation, each year was studied separately. Some estimations for the early years in the study, were made based on the width of the buffer spaces of 2010. Measurements are presented in Appendix I.

Figure 12. Example of how the buffer distances were measured. The yellow arrow represents one measurement. Displayed in the ortho photo 2010 (Borås Stad, 2010a).

2010

The buffer widths of Road 40 (12 m), Sjöhagavägen (10 m) and Alingsåsvägen north of Fjällgatan (10 m), were estimated according to the method above.

1976

The distances to the physical structures along the larger roads were in large extent similar to the situation of year 2010. The same buffer widths were thereby used in the calculations. However, the roads were delimited by different urban borders and did therefore have different lengths.

1964

By visual inspection it was detected that the buffer widths along the corresponding roads in 1964 were significantly narrower. The buffer widths were estimated to; Road 40 (5 m), Sjöhagavägen (5 m), Alingsåsvägen north of Fjällgatan (10 m).

1946

The buffer spaces were basically non-existent at 1946 and were therefore estimated to zero.

Table 8. Buffer space, Borås

Year	Buffer space (m^2)
1946	0
1964	210 500
1976	347 470
2010	367 710

3.5.8 Calculation: Impediments

To estimate how large the impediments were, i.e. the space in between the traffic system, the method in Karlsson's report of Lund "Hur stor plats tar trafiken egentligen" was studied.

To be able to make an estimation of a percentage standard addition to the road space for moving traffic, Karlsson studied samples of crossroads, traffic circles and road sections. The proportion of impediments was then calculated. Traffic separation was not used in 1940 and since Lund at that time had a dense structure; no impediments were added in 1940 (Karlsson, 2011, pp. 47-49). In 1965, 1978 and 2010, 10 % was added to the road space for moving traffic, that was outside the 1940's urban border. The city centre was assumed to have no impediments, not even in the later years of the study.

Visual inspection showed that impediments did occur in Borås in 1946. The difference did make sense, considering that Lund at this time was a small compact city and Borås was more sparse. The impediments in Borås at 1946 were thereby estimated to 5 % of the road space for moving traffic.

To not overestimate the impediments in Borås, the share of impediments, compared to the road space for moving traffic, was estimated to 10 % for 1964, 1976 and 2010. Since the standard addition was set to 10 % of all space for moving traffic, this was a slightly higher value than the one estimated for Lund. Figure 13 shows an example of impediments.

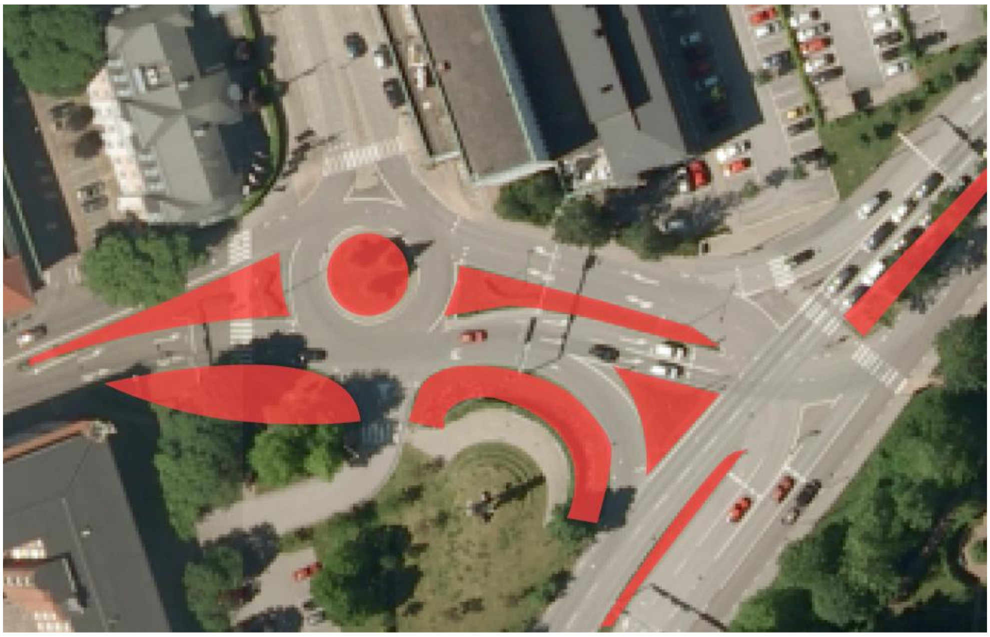


Figure 13. Example of impediments, displayed in the ortho photo from 2010 (Borås Stad, 2010a).

Table 9. Standard addition for impediments in Lund. Percent of the road space for moving traffic, outside the urban border of 1940 (Karlsson, 2011, p. 49).

Year	Standard addition Lund (%)
1940	0
1965	10
1978	10
2010	10

Table 9. Standard addition and calculated impediments, Borås

Year	Percent of space for moving traffic (%)	Impediments Borås (m^2)
1946	5	70 940
1964	10	227 180
1976	10	291 840
2010	10	342 590

3.6 Critique of Method

Some estimations and generalisations have been made in the case study. In the text below, it is discussed why and how some of them were done. Possible sources of error are also discussed.

Road space for moving traffic

Generalisations were done when estimating some road widths, especially in the early years of the study. However, the estimations were done with high accuracy, considering the quality of the input material. All estimations were visually inspected in the aerial and ortho photos, in order to verify that they were reasonable.

Space for parked vehicles

Only parking that was possible to detect from the ortho and aerial photos were included in the study. Single parking on private property was not included and neither was concealed parking. This lead to an underestimation of the space for parked vehicles. In the study, it appeared to be more parking in areas with multifamily houses than in areas with villas. If single parking on private property had been included, one could assume that this relationship would have looked different.

The lower quality made it harder to distinguish parking on the older photos. The occupancy of the parking spaces was lower in the earlier years of the study, which sometimes made it harder to separate parking from other hard surfaces.

Railway

The side area on each side of the railway was estimated after visual inspection of the photos. The side area varies along the railway and the estimation was thereby not always corresponding to the underlying photo.

Buffer space

The calculations of buffer space were a generalisation of the real situation. The four largest roads were included, but in reality, all roads have buffer spaces. The buffer spaces along smaller roads were however considered as negligible in this study, due to their small extent.

Since the buffer width tend to vary a lot along the road, the estimations were intended to represent a reasonable average value of the buffer space. The width of the buffer was considered to be from the side of the road to the closest built structure.

The method used for calculating buffer space in the study is not considered to be accurate enough to make any detailed conclusions in single cases. It does however provide an overall picture.

Impediments

To estimate a standard addition for impediments was difficult. For comparison, the method in Karlsson’s report was studied. Visual inspection indicated that Borås had a larger share of impediments than Lund. The standard additions used in the study of Lund were therefore adjusted to represent Borås in a better way.

The values gave an indication of the situation and since the same method was used for all four years in the study, the comparison between them was considered as relevant. Since the method used for Lund was studied, also the comparison with that study was considered to be relevant.

Like the method of buffer space, the method used for calculating impediments in the study is not considered to be accurate enough to make any detailed conclusions in single cases. It does however also provide an overall picture. If more studies are done concerning traffic space, these methods could be further developed.

3.7 Result

Below, the result of the case study is presented in tables. They are divided into respective year, with 1946 first.

Year 1946

The share of the total urban area and the distribution of traffic space of 1946 is presented in table 11. The population of the urban area was in this year 54 141 inhabitants.

Table 11. Distribution of traffic space 1946.

	Space (m^2)	Share of urban area (%)
Urban area	16 366 500	-
Road space for moving traffic	1 418 740	8,7 %
Space for parked vehicles	74 790	0,5 %
Railway	355 510	2,2 %
Buffer space	0	0,0 %
Impedimets	70 940	0,4 %
Traffic space, total	**1 919 980**	**11,7 %**

Year 1964

The share of the total urban area and the distribution of traffic space of 1964 is presented in table 12. The population of the urban area was in this year 68 797 inhabitants.

Table 12. Distribution of traffic space 1964.

	Space (m^2)	Share of urban area (%)
Urban area	23 501 540	-
Road space for moving traffic	2 271 840	9,7 %
Space for parked vehicles	455 060	1,9 %
Railway	396 850	1,7 %
Buffer space	210 500	0,9 %
Impedimets	227 180	1,0 %
Traffic space, total	**3 561 430**	**15,2 %**

Year 1976

The share of the total urban area and the distribution of traffic space of 1976 is presented in table 13. The population of the urban area was in this year 66 684 inhabitants.

Table 13. Distribution of traffic space 1976.

	Space (m^2)	**Share of urban area (%)**
Urban area	27 517 540	-
Road space for moving traffic	2 918 420	10,6 %
Space for parked vehicles	935 160	3,4 %
Railway	413 300	1,5 %
Buffer space	347 470	1,3 %
Impedimets	291 840	1,1 %
Traffic space, total	**4 906 190**	**17,8 %**

Year 2010

The share of the total urban area and the distribution of traffic space of 2010 is presented in table 14. The population of the urban area was in this year 66 273 inhabitants.

Table 14. Distribution of traffic space 2010.

	Space (m^2)	**Share of urban area (%)**
Urban area	32 002 590	-
Road space for moving traffic	3 425 910	10,7 %
Space for parked vehicles	1 339 810	4,2 %
Railway	410 570	1,3 %
Buffer space	367 710	1,1 %
Impedimets	342 590	1,1 %
Traffic space, total	**5 886 590**	**18,4 %**

4 Discussion and Comparison with Traffic Space in Lund

In the discussion, the key figures are analysed in order to summarise the result. They are presented in diagrams to make the development over the studied period clear. The key figures are also compared with the result of Lund continuously in the discussion. Finally, it is also discussed where Borås has the highest concentration of parking.

In the diagrams where Borås and Lund are compared, no adjustments have been done to compensate that the studied years do not completely match. This difference was considered to be negligible, and therefore only the years for the study of Borås are displayed.

Key figures of the study:

- Traffic space / urban area [%]
- Traffic space [m^2]
- Population / urban area [inhabitants / km^2]
- Traffic space / population [m^2 / inhabitant]

Other presented data:

- Areas with high concentration of parking
- Car ownership [cars / 1000-inhabitants]

Traffic space / urban area

The value of traffic space divided by total urban area shows how large share of the city that traffic makes use of. Below, two diagrams show how those values have changed during the studied period for Borås and Lund respectively[3]. The diagrams also show the distribution of the different categories of traffic space. See Figure 14 and 15. The diagrams presents how the different categories have developed during the studied period, as well as how they have changed relative each other. Since the urban density was different in the two cities, these diagrams do not provide a fair comparison of how space efficient the traffic systems are. Thus, a city with large urban sprawl can have a relatively small share of traffic space, due to a large total urban area.

Table 15. Distribution of traffic space in Borås, from 1946 to 2010. Share of urban area.

	1946	1964	1976	2010
Road space for moving traffic	8,7 %	9,7 %	10,6 %	10,7 %
Space for parked vehicles	0,5 %	1,9 %	3,4 %	4,2 %
Railway	2,2 %	1,7 %	1,5 %	1,3 %
Buffer space	0,0 %	0,9 %	1,3 %	1,1 %
Impediments	0,4 %	1,0 %	1,1 %	1,1 %
Traffic space, total	**11,7 %**	**15,2 %**	**17,8 %**	**18,4 %**

[3] Note: Different years are studied in Borås and Lund.

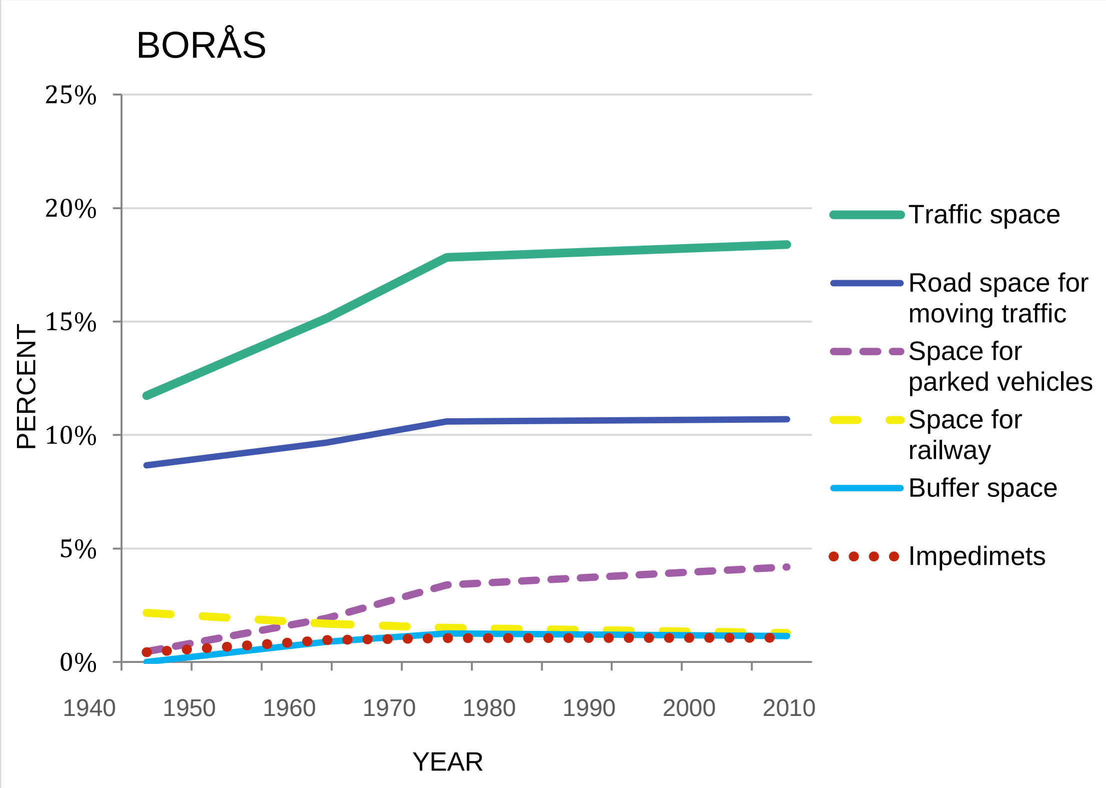


Figure 14. Share of traffic space in Borås in relation to total urban area. Also the distribution of the different categories of traffic space. Studied years: 1946, 1964, 1976 and 2010.

As the diagram in Figure 14 shows, the share of traffic space in Borås increased from 11.7 % to 18.4 % during the studied period. The increase was detectable over the whole period, but largest from 1946 to 1976.

The most significant change, was the space for parked vehicles. This category increased from 0.5 % to 4.2 % from 1946 to 2010. Also the road space for moving traffic did increase up to 1976, but stagnated after that. These two increasing curves could be explained by the traffic politics that were conducted at the time and the belief that car traffic was the future (see Chapter 2.1.3. Traffic planning in Swedish cities during the 20th century).

The yellow line represents space for railway and shows a decreasing curve. The reason why space for railway decreased, was that the number of railway tracks were nearly constant, while the station and depot areas decreased. The diagram shows that railway is a space efficient mode of transport. Especially if space for depots in central parts of cities can be minimised, since the actual railway track only makes use of a small amount of space.

The share of buffer space was relatively constant, except a small increase between 1946 and 1964. This increase can be derived to increased car traffic and higher speed limits, which creates a need for wider buffer zones.

The share of impediments almost followed the same curve as the buffer space. The increase between 1946 and 1964 could be explained by traffic separation and a planning with cars in focus.

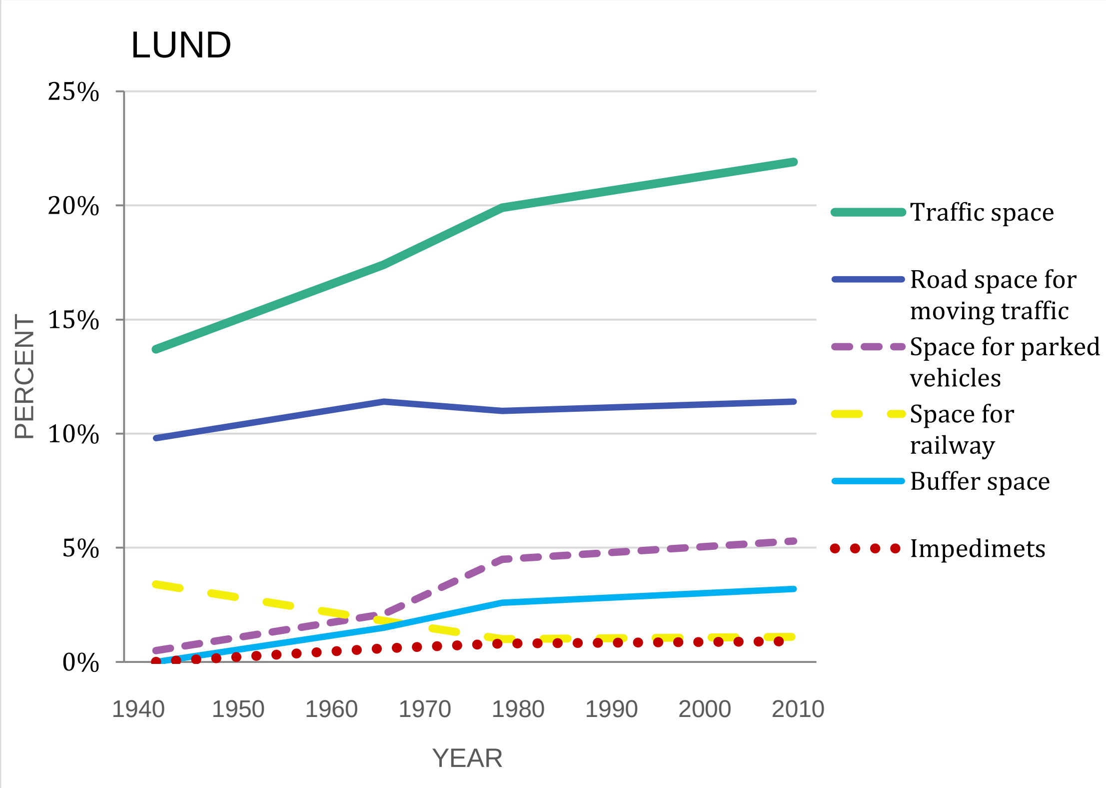


Figure 15. Share of traffic space in Lund in relation to total urban area. Also the distribution between the different categories of traffic space. Studied years: 1940, 1965, 1978 and 2010.

Figure 15 shows the share and distribution of traffic space in Lund. When comparing the diagrams of Borås and Lund the similarities are obvious. The curves from the two cities followed the same patterns, to a large extent. This was of great interest, regarded that the cities have a rather different urban form. Where Lund has a round, compact shape, and Borås has grown along the main roads and has a lower urban density.

Buffer space was the only category that differed a little bit, where Lund had a higher value. That was a realistic result, since Lund has more distinctive buffer zones along the larger roads. Additionally, the largest road in Borås, Road 40, passes through the city centre with almost non-existent buffer zones.

The diagram also shows that Lund had a higher share of total traffic space than Borås. The reason for that was, most likely, that Lund had a higher urban density.

Traffic space

The diagram in Figure 16 shows the growth of traffic space in absolute numbers. The traffic space was increasing over the whole studied period, which was understandable since the urban area increased for every studied year. Of interest was that the increase declined after 1976, even though the urban area continued to increase in a more continuous way. That shows that traffic space expanded greatly during the mid 1900's, when the car was integrated in Swedish cities. The fact that the increase was lower after 1976, could indicate that the transformation of the existing urban areas were mostly finished at this point.

Table 16. Traffic space in Borås in square meters, from 1946 to 2010.

Year	Road space
1946	1 919 980
1964	3 561 430
1976	4 906 190
2010	5 886 590

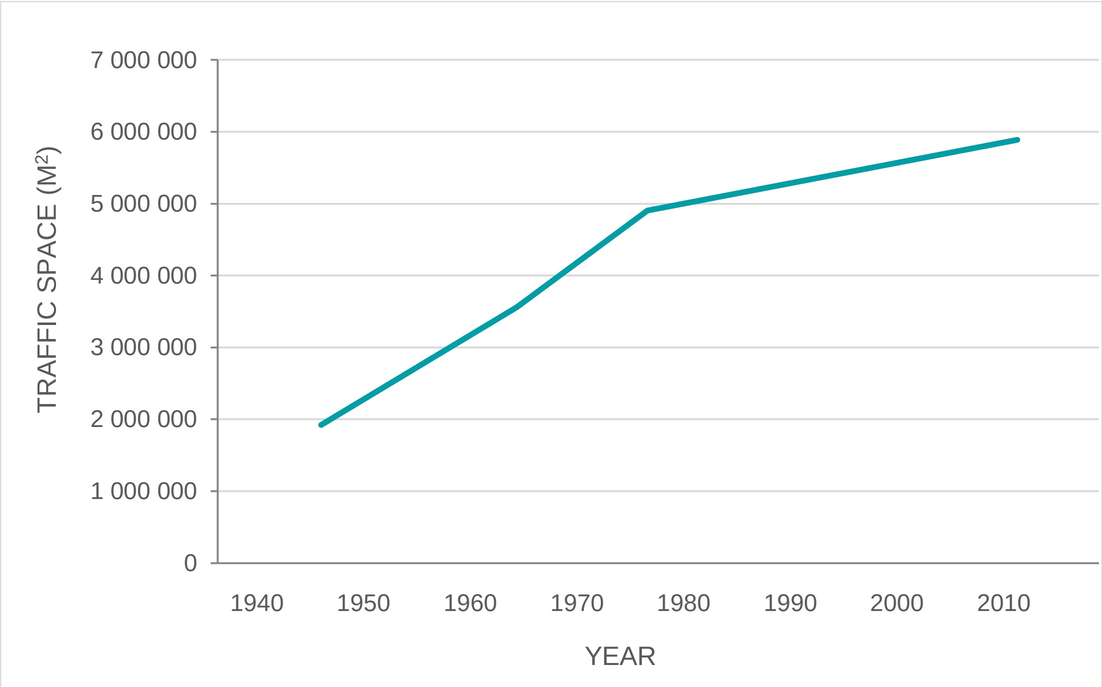


Figure 16. Traffic space in square meters, from 1946 to 2010.

Population / urban area

The diagram in Figure 17 shows the urban density of Borås and Lund. These curves are substantial due to the correlation between the urban density and transport energy, see Chapter 2.2.1. Urban density and energy consumption.

Table 17. Urban density of Borås, from 1946 to 2010.

Year	Inhabitants / Urban area (inh / km²)
1946	3 308
1964	2 927
1976	2 423
2010	2 071

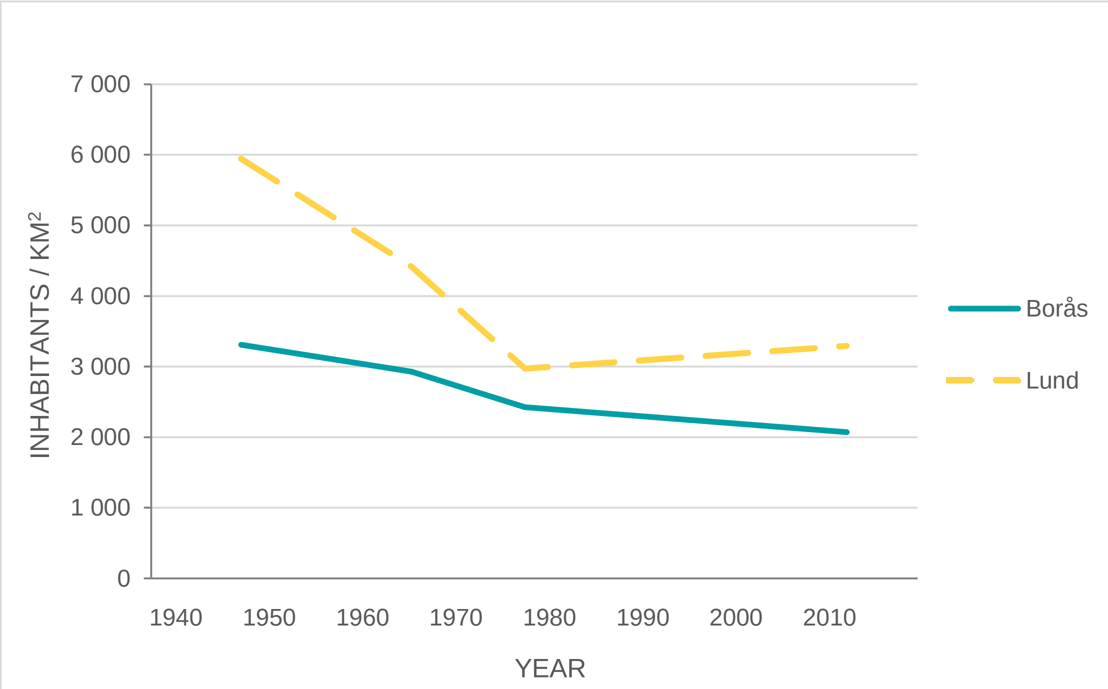


Figure 17. Urban density of Borås and Lund, from 1946 to 2010.

Except that Lund had a steeper curve, the diagram shows that the cities followed the same trend up to 1976. After that the urban density of Lund started to increase again, while the same figure for Borås did continue to decrease. In this study, the reason for this development was not investigated. However, of interest was that Lund, in 1976, broke the trend of a decreasing urban density. A trend that generally indicates more transports by car and more traffic space.

The reason that Lund had a steeper curve from 1946 to 1964 could be assumed to depend on that Lund in 1946 was a small, dense city of medieval character. Thus, with this rapid development, Lund approached a more average urban density of Swedish cities.

Traffic space / population

The diagram in Figure 18 shows square meters of traffic space per capita. It gives an indication of how space efficient the traffic systems were. That could also be an indication of how car dependent the cities were, since cars demand a large amount of space.

Table 18. Traffic space per inhabitant in Borås, from 1946 to 2010.

Year	Traffic space / Inhabitant (m2/inh)
1946	35
1964	52
1976	74
2010	89

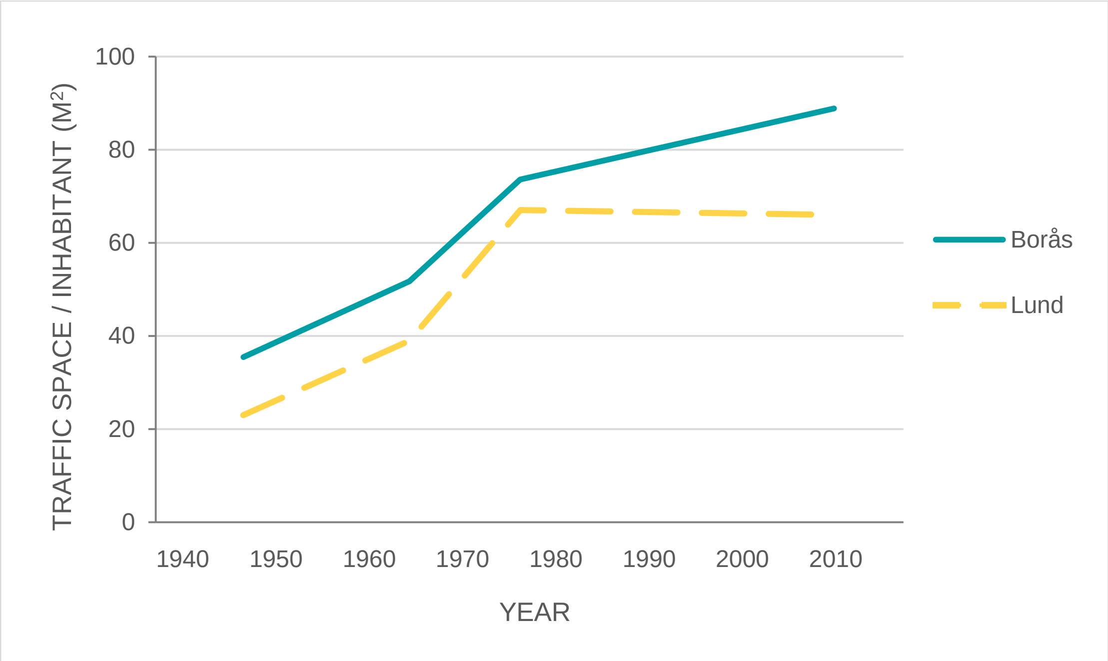


Figure 18. Traffic space per inhabitant, from 1946 to 2010.

As in Figure 17, of urban density, the cities had similar curves regarding traffic space per inhabitant, up to 1976. It was understandable that they increased up to this point, since the usage of cars increased markedly these years. It was, however, substantial that Lund from 1976 to 2010 had a decreasing curve, while the same curve for Borås continued to increase. The point where the "traffic space / inhabitant" of Lund started to decrease, correlates with the point where Lund started to have an increasing density curve. This indicated that Lund in this period managed to host more people, without expanding the traffic system in the same extent as earlier. It is, however, not examined in this study what actions that supported this development.

Areas with high concentration of parking

The pink fields on the map in Figure 19 represent parking. Those areas with highest concentration of parking were, by visual inspection, identified and marked with blue circles. As the figure shows, the areas with a large concentration of parking were mainly used for retail and industrial activity. A high concentration of parking indicates that an area is an important travel destination and that transports to these areas in a large extent are made by car. A reason for why these areas were dominated by industrial and retail establishments, could be that goods often were transported to these areas. Another reason could be that safe and qualitative options not were provided. Areas planned for cars often reduce the attractiveness of other modes of transport. In Borås, most areas with high concentration of parking were located in central location. That could be considered beneficial, in order to increase accessibility of other modes of transports.

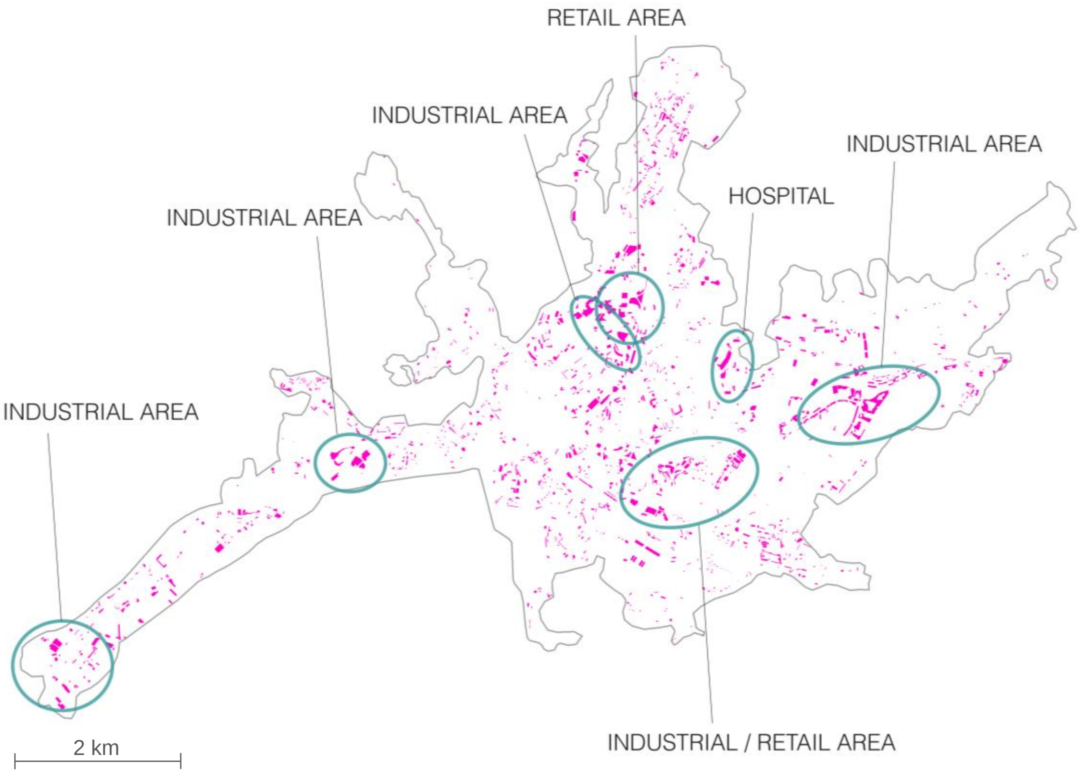


Figure 19. The pink fields on the map represent parking in Borås 2010. The blue circles shows areas with a high concentration of parking.

Car ownership

Figure 20 displays the development of car ownership in the municipality of Borås and Lund from 1974 to 2010. The diagram shows that the curves representing car ownership look very similar, with the exception that Borås had a greater increase. Even though the curves represent the car ownership of the municipalities, they were assumed to give an indication of the situation also in the urban area. The development of the car ownership was, in some extent, also assumed to reflect the traffic by car.

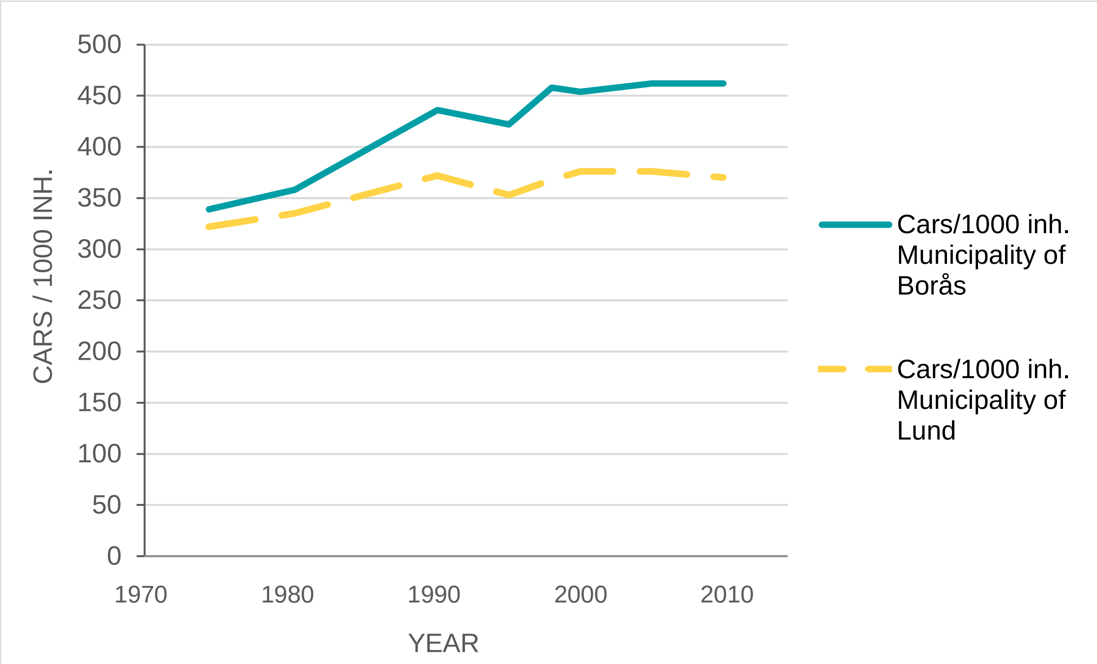


Figure 20. Diagram of car ownership in the municipalities of Borås and Lund (Statistiska Centralbyrån, 2013).

5 Conclusion and further studies

This chapter addresses the reliability of the study, further relevant studies and conclusion that are based on the result and discussion.

5.1.1 Reliability analysis

In addition to Subchapter 3.5. Critique of Method, this section will concern the reliability of this study.

This analysis has been made with highest possible accuracy, considering the time span and input data. The result in the study is not intended to be seen as an exact measure of the traffic space in Borås. However, the study is considered to give a good indication of how the traffic space was distributed and how the development looked like in the studied time period.

The scarce availability of data between 1976 and 2010, made that period longer than the other periods. In order to get more detailed curves in the diagrams, it would have been interesting to study one year in this interval.

The method used in the study of Lund has been taken into consideration to be able to make an accurate comparison. However, the studies were done with different material, at different time by different persons. Thereby may some variations in the result occur.

In 2013, there were about eight times more full time students in Lund than in Borås. Students can in most cases not afford a car and they are necessarily not registered in the city they live in. However, no considerations have been taken to this in the study or in the conclusion.

As written in the discussion, no adjustments have been made in the diagrams in order to compensate that different years are studied in Borås and Lund. The studied years are however considered to correspond well enough to make a relevant comparison.

5.1.2 Further studies

This study shows similarities and differences in traffic space between Borås and Lund. Since traffic space is a crucial part in sustainable urban planning, more studies on this topic would be useful. For example could more cities be studies, to find more correlations or differences. The method used in this study could also be developed, especially regarding concealed parking, buffer space and impediments.

If data can be found, the period between 1976 and 2010 could be useful to study more. That would give a more updated picture of how traffic space has developed during the years that sustainability has been discussed in a larger extent. Also a study that separates walkways, bicycle paths and bus lanes from car lanes would be interesting.

5.1.3 Conclusion

Traffic space in Borås

The general trends of the traffic space in Borås, were that road space for moving traffic and space for parked vehicles increased markedly up to the mid-seventies. After that the increase declined. A similar pattern apply to car ownership, while there was a rather constant decline of urban density during the studied period. Space for railway was the only category that decreased during this period.

The most remarkable change was the category space for parked vehicles, which increased from 0.5 % to 4.2 %. In 2010, this category made use of almost half of the space that moving vehicles made use of. Since the car ownership also did increase and every vehicle needs more than one parking lot, this was a predictable development. It means however, that areas that could be used for other purposes, became occupied. A regulation of parking could be one, among other, actions to break the trend of increasing traffic space.

A continued development in line with the period 1946 to 2010, would further promote car traffic. However, since the last studied period is rather long and reaches from 1976 to 2010, no conclusions regarding the present trend can be drawn from this study.

One goal of the vision “Borås 2025” is to create a dense, mixed-use city centre, with a dominating public transport. Moreover, it should in 2025 be easy to travel by bicycle and walking between the different parts of Borås. If these goals are fulfilled, better conditions for a lower car dependency would be created. That would also, most likely, change the need of traffic space. If the hypothesis of peak car proves to be correct, car traffic also will decrease in general. These factors could lead to multiple positive effects, such as lower transport energy, less emissions, more space for housing and planned green areas, increased urban liveability, and increased public health.

Similarities and differences in traffic space between Borås and Lund

There were large similarities between the share of traffic space in the two cities. The result shows that all categories of traffic space, followed the same pattern in both cities. That is of great interest, especially since the urban form of the cities are different. The similarities in the development of traffic space in Borås and Lund make it reasonable to assume that these trends also might hold for other Swedish cities. Furthermore, factors like national policies and trends could be assumed to have affected Swedish traffic planning more than each single city’s policies.

One distinct trend for both cities was that the interval 1964 to 1976 was characterised by large traffic space expansions. That could be explained by the great expansion of car traffic and traffic separation that took place in Sweden in this period. The cities were at this time adapted to fit a society with cars.

All though the overall similarities were markedly between the traffic space in the two cities, there were also some general differences. Borås had, in the studied period, more traffic space per capita and was less dense than Lund. Borås also had a higher rate of car ownership in the municipality, a difference that grew even more from 1964 to 2010. These factors make it reasonable to assume that Borås had a higher car dependence during the studied period. That is however not that controversially, since Lund in general is considered as a dense and bike friendly city.

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Appendices

Appendix I: Calculations Buffer Space

Buffer space 2010

Table 6. Measurements Road 40, 2010.

Number	Type	Distance (m)	Comment
1	Road	16	
2	Road	12	
3	Road	11	
4	Railway	12	
5	Industrial area	12	
6	Building	1	Disregarded
7	Parking	5	
8	Road	13	
9	Parking	15	
10	Building	13	
11	Building	9	
12	Road	9	
13	Road	10	
14	Road	3	
15	Building	36	Disregarded
16	Road	23	
17	Road	16	
18	Road	21	
19	Parking	8	
20	Parking	9	
21	Parking	8	
22	Parking	8	
23	Parking	9	
24	Road	26	
Avarage Buffer, Road 40:		**12**	

Table 7. Measurements Sjöhagavägen, 2010.

Number	Type	Distance (m)	Comment
1	Parking	5	Disregarded
2	Parking	5	
3	Road	10	
4	Parking	25	
5	Road	10	
6	Building	26	Disregarded
7	Road	6	
Avarage Buffer, Sjöhagavägen:		**11**	

Table 8. Measurements Alingsåsvägen north of Fjällgatan, 2010.

Number	Type	Distance (m)	Comment
1	Bicycle path	10	
2	Road	6	
3	Building	17	
4	Bicycle path	20	Disregarded
5	Private garden	7	
6	Private garden	12	
7	Parking	11	
8	Parking	5	Disregarded
9	Garage	5	
10	Building	14	
11	Privat garden	5	
Avarage Buffer, Alingsåsvägen north of Fjällgatan		**10**	

Table 9. Measurements Gånghestervägen, 2010.

Number	Type	Distance (m)	Comment
1	Parking	7	
2	Building	19	
3	Railway	22	Disregarded
4	Building	10	
5	Building	5	
6	Parking	4	Disregarded
7	Building	4	
8	Building	16	
Avarage Buffer, Gånghestervägen:		**10**	

Table 10. Calculation of buffer spaces 2010.

Road	Buffer width (m)	Road length (m)	Buffer space (m2)
Road 40	12	8937	214 490
Sjöhagavägen	11	2198	48 360
Alingsåsvägen north of Fjällgatan	10	3183	63 660
Gånghestersvägen	10	2060	41 200
Total, buffer space 2010			**367 710**

Buffer space 1976

Table 11. Calculation of buffer spaces 1976.

Road	Buffer width (m)	Road length (m)	Buffer space (m^2)
Road 40	12	7828	187 870
Sjöhagavägen	11	2198	48 360
Alingsåsvägen north of Fjällgatan	10	3171	47 820
Gånghestersvägen	10	2391	63 420
Total, buffer space 2010			**347 470**

Buffer space 1964

Table 12. Calculation of buffer spaces 1964.

Road	Buffer width (m)	Road length (m)	Buffer space (m^2)
Road 40	5	7828	78 280
Sjöhagavägen	5	2098	20 980
Alingsåsvägen north of Fjällgatan	10	3171	47 820
Gånghestersvägen	10	2391	63 420
Total, buffer space 2010			**210 500**